PB-217 649

MISSOURI-SOURIS DEVELOPMENT AREA WATER POLLUTION INVESTIGATION

Public Health Service
Kansas City, Missouri

January 1952

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 217 649

TP
M 177

Water Pollution Series No. 32

LIBRARY
SANITARY ENGINEERING CENTER
CINCINNATI, OHIO

For Clean Water — "One River, One Plan"

MISSOURI-SOURIS DEVELOPMENT AREA
WATER POLLUTION INVESTIGATION

A COOPERATIVE STATE-FEDERAL REPORT ON WATER POLLUTION

NOVEMBER 1951

MONTANA
N. DAKOTA
S. DAKOTA
MINN.
WYOMING
IOWA
NEBRASKA
COLORADO
KANSAS
MISSOURI

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

MINNESOTA
Department of Health

MONTANA
Board of Health

NORTH DAKOTA
Department of Health

SOUTH DAKOTA
Department of Health

WYOMING
Department of Health

FEDERAL SECURITY AGENCY
Public Health Service

MISSOURI-SOURIS DEVELOPMENT AREA

WATER POLLUTION INVESTIGATION

JANUARY 1952

PUBLIC HEALTH SERVICE
DIVISION OF WATER POLLUTION CONTROL
MISSOURI DRAINAGE BASIN OFFICE

STATE OF MINNESOTA
STATE DEPARTMENT OF HEALTH

STATE OF NORTH DAKOTA
STATE DEPARTMENT OF HEALTH

STATE OF MONTANA
STATE BOARD OF HEALTH

STATE OF SOUTH DAKOTA
STATE DEPARTMENT OF HEALTH

STATE OF WYOMING
STATE DEPARTMENT OF HEALTH

Prepared by the above Health Agencies
in cooperation with, and at the request of
the Bureau of Reclamation

Public Health Service Publication No. 177

MISSOURI-SOURIS DEVELOPMENT AREA WATER POLLUTION INVESTIGATION

TABLE OF CONTENTS

Page

Introduction 1

Authority 2

Acknowledgment 3

Summary 7

Conclusions 11

Recommendations 12

Missouri-Souris Development Area - General Section 13

Missouri River Sub-Basin 83

Souris River Sub-Basin 115

Red River Sub-Basin 145

Appendixes 189

INTRODUCTION

The Missouri-Souris portion of the land and water resources development program for the Missouri River Basin includes that reach of the Missouri River from below the mouth of Milk River in Montana to the mouth of Spring Creek, South Dakota, the Devils Lake Area, the James River Basin, and the United States portions of the Souris and Red River Basins (figures 1 and 2). The plan calls for diversion of Missouri River water at strategic points for multipurpose use and to supplement available water in the Souris, Red, and James River Basins. This report covers the Missouri-Souris-Red area. The James River Basin will be presented in another report.

Among the many contemplated water uses of the resource conservation plan are those for municipal, industrial, public health, sanitation and related purposes. In order to determine these needs, information is required on present water quantity and quality; and types, sources, and extent of pollution in streams of the region.

Recognizing that a comprehensive investigation of water pollution aspects of the Basins should be made in order to ascertain the extent and nature of existing pollution and to secure basic data for water utilization planning, the Bureau of Reclamation, Department of the Interior, and the North Dakota State Department of Health, requested the Public Health Service, Federal Security Agency, to assume responsibility for a cooperative investigation of the Basins affected. A memorandum of agreement entitled "Memorandum of Understanding Respecting Joint Program for Public Health Investigations of the Souris-Red River of the North Basins" was entered into by Region 6, Bureau of Reclamation and the Missouri Drainage Basin Office, Division of Water Pollution Control, Public Health Service, and became effective March 20, 1950. The complete text of the Memorandum is given in appendix A.

In accordance with the text of the Memorandum of Understanding, the stream pollution investigation included the following: "(a) the extent, types, and major sources of pollution; (b) a review of existing laws and pending legislation regarding pollution of public waters in the States[1] of Montana, North Dakota, and Minnesota; (c) minimum stream flows necessary for public water supplies and other miscellaneous purposes, and for sanitation purposes as related to present and possible future pollution; (d) quality of water for municipal requirements and other miscellaneous purposes; (e) public health benefits of water pollution abatement resulting from the conservation, regulation, and use of water supplies under the Missouri River Basin program; (f) recommendations for pollution abatement and existing plans therefor; (g) effect of current and possible future pollution on water to be used for irrigation; and (h) other public health considerations of the water development program in the Basin."

The Missouri Drainage Basin Office of the Public Health Service assigned two engineers to the North Dakota State Department of Health in June 1950 to assist in collection of data. The Minnesota Department of Health conducted investigations in its portion of the area;

---

[1] South Dakota and Wyoming later included.

an engineer was assigned part time to the Montana State Board of Health. Surveys on sources of pollution proceeded throughout the summer, fall, and winter of 1950-51. Stream samples were collected and examined during August 1950 and under ice cover during January 1951. The preparation and development of this report have been made with close coordination and assistance of cooperating agencies who furnished much of the basic information.

This report has been founded upon the specified objectives in the Memorandum of Understanding. A general section deals with over-all water supply and water pollution problems pertinent to the area and includes survey methods, review of State Water Pollution Control Law, conclusions and recommendations. The major sub-basins are discussed in detail in separate sections of the report. Pertinent detail information, laboratory and flow data, and other presentations are included as appendixes.

AUTHORITY

This report is compiled under the authority accorded the Public Health Service in section 2(a) of Public Law 845, 80th Congress, which reads as follows:

"The Surgeon General shall, after careful investigation, and in cooperation with other Federal agencies, with State water pollution agencies and interstate agencies, and with the municipalities and industries involved, prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary conditions of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses. For the purpose of this subsection the Surgeon General is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substance which may deleteriously affect such waters."

In addition to the foregoing, Title III, Part A, Section 301 of Public Law 410, gives the Public Health Service the following responsibility:

"The Surgeon General shall conduct in the Service, and encourage, cooperate with, and render assistance to other appropriate authorities, scientific institutions, and scientists in the conduct of, and promote the coordination of, research investigation, experiments, demonstrations and studies relating to the cause, diagnoses, treatment, control, and prevention of physical and mental diseases and impairments of men, including water purification, sewage treatment, and pollution of lakes and streams."

ACKNOWLEDGMENT

This report resulted from the splendid cooperation and support provided by the various State and Federal agencies, communities in the area, and industries contacted during the survey. Help rendered by all is gratefully acknowledged.

Special recognition is made of the support, cooperation, and encouragement of water pollution control agencies of the States concerned, particularly the North Dakota State Department of Health, represented by Dr. R. O. Saxvik, State Health Officer, and Chief Sanitary Engineer J. H. Svore, Director of Environmental Sanitation Service. The major portion of the area under consideration is in the State of North Dakota. The Minnesota Department of Health was represented by Dr. A. J. Chesley, State Health Officer, and F. L. Woodward, Chief, Section of Environmental Sanitation; the Montana State Board of Health by Dr. G. D. Carlyle Thompson, State Health Officer, and H. B. Foote[1], Director, Division of Sanitary Engineering; the South Dakota State Department of Health by Dr. G. J. Van Heuvelen, State Health Officer, and Charles E. Carl, Director, Division of Sanitary Engineering; and the Wyoming Department of Public Health by Dr. Franklin D. Yoder, State Health Officer, and L. O. Williams, Director, Division of Environmental Sanitation.

The broad aims of the investigation were specified in the Memorandum of Understanding entered into by Region 6, Bureau of Reclamation, represented by K. F. Vernon, Regional Director, and W. E. Rawlings, Assistant Regional Director, who have done much to promote these activities, and by the Missouri Drainage Basin Office, Public Health Service, represented by Glen J. Hopkins, Basin Engineer. The Missouri-Souris District Office of the Bureau of Reclamation at Bismarck, North Dakota, through Bruce Johnson, District Manager, and S. Sundahl, Planning Engineer, contributed needed information and provided other assistance.

Stream discharge data provided by the U. S. Geological Survey, particularly by Chief Engineer Harlan Erskine and staff of the Bismarck District Office; and studies of the Fish and Wildlife Service of the Department of Interior, and of the Corps of Engineers, Department of Defense, were also of great value.

Technical reviews of this report were made by:

- The Public Health Service, Federal Security Agency
    - Water Pollution Control Division, Washington, D. C.
    - Environmental Health Center, Cincinnati, Ohio
    - Upper Mississippi-Great Lakes Drainage Basin Office, Chicago, Illinois
    - Region IX Office, Denver, Colorado
    - Region VII Office, Kansas City, Missouri
- The Department of the Interior
    - Bureau of Reclamation, District 6, Billings, Montana
    - Missouri Basin Field Committee, Billings, Montana
    - Fish and Wildlife Service, Billings, Montana, and Minneapolis, Minnesota

---

[1] Director H. B. Foote has retired. Mr. Claiborne W. Brinck is now Director, Division of Environmental Sanitation.

National Park Service, Omaha, Nebraska
Geological Survey, Rolla, Missouri, and Bismarck, North Dakota
The Corps of Engineers, U. S. Army, Department of Defense
Missouri River Division, Omaha, Nebraska
St. Paul District, St. Paul, Minnesota
The Department of Commerce, Denver, Colorado
The Department of Agriculture, Lincoln, Nebraska
The Federal Power Commission, Chicago, Illinois

This report was prepared in close collaboration with the water pollution control agencies of North Dakota, Minnesota, Montana, Wyoming, and South Dakota. They have reviewed the report and approved its contents as it applies to their respective States.

Staff

A. Missouri Drainage Basin Office, Public Health Service

Glen J. Hopkins, Senior Sanitary Engineer
Officer in Charge

Ralph Porges, Senior Sanitary Engineer
Assistant Basin Engineer

Joe K. Neel, Biologist

Francis L. Nelson, Assistant Sanitary Engineer

William B. McMurtray*, Public Health Engineer

Keith S. Krause, Senior Assistant Sanitary Engineer

Daniel J. Wiener, Sanitary Engineer

Eugene Rothman*, Public Health Engineer

Clarence Monday, Biologist

B. North Dakota State Department of Health

Dr. R. O. Saxvik, State Health Officer

J. H. Svore, Chief Sanitary Engineer
Chief of Environmental Sanitation Service

W. Van Heuvelen, Director,
Division of Water Pollution Control

M. E. Koons, Chief of Laboratory Services

Robert Francis, Associate Chemist

Hazel Heimstra, Associate Bacteriologist

---

*Resigned prior to completion of report

A. A. Gustuson, Director, Grand Forks Laboratory

A. L. Bavonne, District Engineer, and staff,
First District Health Unit, Minot, North Dakota

C. Minnesota Department of Health

Dr. A. J. Chesley, State Health Officer
Secretary and Executive Officer

F. L. Woodward, Chief
Section of Environmental Sanitation

Harvey G. Rogers, Director,
Division of Water Pollution Control

Duane E. Cozart, Associate Biologist

Richard Owens, Sanitary Engineer

D. Montana State Board of Health

Dr. G. D. Carlyle Thompson, State Health Officer,
Executive Officer

C. W. Brinck, Director,
Division of Environmental Sanitation

H. B. Foote, Director,
Division of Sanitary Engineering

E. South Dakota State Department of Health

Dr. G. J. Van Heuvelen, State Health Officer

Charles E. Carl, Director,
Division of Sanitary Engineering

R. J. Stapf, Chief, Sewage Section

F. Wyoming Department of Public Health

Dr. Franklin D. Yoder,
State Health Officer, Director

L. O. Williams, Director,
Division of Environmental Sanitation

SUMMARY

The Missouri-Souris Development Area is delimited in this report to encompass the Missouri River watershed from the Milk River in Montana to Spring Creek in South Dakota, excluding the Yellowstone River, that portion of the Souris River drainage in the United States including landlocked Devils Lake Area, and the Red River of the North and its tributaries south of the International Boundary. The development of land and water resources will affect parts of the States of Montana, Minnesota, North Dakota, South Dakota and Wyoming.

Scarcity of water, either from ground or surface sources, has been the main deterrent to economic development of the major portion of the region. Agriculture and its associated industries are principal sources of livelihood. Although soils of the Red River Valley are extremely fertile, in other areas it varies from very poor to good. The climate is rigorous but the growing season is sufficient to produce wheat, rye, potatoes, sugar beets, and legumes. The western extremities of the region are particularly suited to livestock. Cities and towns form marketing and distribution centers for surrounding farms and ranches. Local industry usually consists of creameries; meat processing, ranging from very small slaughter houses to large commercial packing plants; flour milling and transportation services. Beet sugar refining, an operation of considerable magnitude, is concentrated at Moorhead, and East Grand Forks, Minnesota, in the Red River Valley. Lignite and oil resources have not been extensively developed.

The water resources development plan (see figure 2) proposes conservation of available surface and ground waters within the region and importation of water from the Missouri River. Irrigation is envisioned for areas adjacent to the streams within the Missouri Sub-Basin, for a considerable portion of the Souris Sub-Basin, and for sizable tracts along the Sheyenne River. Diversion, storage, and conservation as proposed will supplement municipal and industrial water supplies and improve stream sanitation. It will rehabilitate Devils and Stump Lakes, enhance waterfowl production, increase hydroelectric power, and minimize the effects of floods.

Surface water supplies serve 146,580 people in 25 municipalities with 14.828 M.G.D., and 8 industries, exclusive of 4 power plants using only cooling water, with 12.676 million gallons per day. Ground sources are utilized by 153,210 persons (168 communities) to the extent of 10.509 M.G.D., and 132 industries with a daily demand of 3.202 million gallons. In general, mineral content of the water is high. Excepting the Missouri River and eastern tributaries of the Red River, both surface and ground waters are inadequate and of poor quality.

The pollution effects of municipal and industrial wastes discharged were evaluated. The Red River appears to be the most seriously polluted major stream in the region; sections of the Souris River were also found to be excessively polluted. The survey revealed 275 separate sources of waste, 165 from municipalities and 110 from industries having separate outlets. One hundred thirty-five municipalities provide some type of treatment for their wastes as indicated in the following table:

Preceding page blank

Missouri-Souris Development Area - Existing municipal* sewage treatment facilities

Degree of treatment provided	Number		Population served
	Municipalities	Plants	
Minor[a]	25	26	30,000
Primary	67[b]	68	84,700
Secondary	43[c]	41	130,100
No treatment	35	-	69,510

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

[a] Septic tank.

[b] Includes one new system under construction.

[c] Includes four new systems under construction.

Sixty-seven industrial establishments provide treatment.

Seventy-nine municipal and 32 industrial waste treatment plants are considered satisfactory from a capacity viewpoint. Eighty-three municipal and 32 industrial waste treatment plants are operated satisfactorily. These data are summarized below:

Missouri-Souris Development Area - Adequacy of existing waste treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:			
		Capacity		Operation	
		Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
Municipal*	130	79	51	83	47
Industrial**	67	32	35	32	35

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Municipal and industrial treatment needs are tabulated as follows:

Missouri-Souris Development Area - Municipal and industrial waste treatment needs

	Municipal*		Industrial**
Needs	Number	Population served by facilities	Number
New plant	61	101,080	71[a]
Enlargement or addition to existing plant	17	90,720	3
Replace existing plant	7	26,310	0
No project required	80	93,910	36

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

[a] The recommended solution for three of these industries would entail connection to municipal sewage.

Cost of installing recommended treatment facilities is estimated at $11,789,000.

The status of abatement works is given in the following table:

Missouri-Souris Development Area - Status of municipal and industrial action on pollution abatement needs

	Number	
Status of action	Municipalities*	Industries**
No formal action	68	71
Abatement ordered	0	0
Plans under preparation	6	2
Final plans approved	8	0
Construction awaits financing	0	0
Under construction	8[a]	1

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

[a] Includes five new systems.

No formal action has been taken in 139 instances.

Progress in pollution abatement since 1946 is indicated as follows:

Missouri-Souris Development Area - Progress in pollution abatement

	Municipal		Industrial	
Year	Plants completed	Design population	Plants completed	Amount of waste treated
1946	3	3,300	0	-
1947	3	4,800	1	126,000
1948	6	5,400	0	-
1949	4	1,825	0	-
1950	11	18,375	0	-
1951	8	41,350	0	-

From 1946 to the present, 35 municipal sewage treatment plants and one industrial waste treatment works have been constructed. The construction program gained impetus in 1950 and 1951 and this trend may be expected to continue as a result of increased activities in pollution control by the State water pollution control agencies.

The review of State law indicates that Montana, North Dakota, and South Dakota have need for more adequate statutory backing. Minnesota has effective water pollution control laws and Wyoming has recently amended its laws to provide for a more comprehensive definition of pollution. Yet, much has been done by all States, and much can be done under existing law.

The interstate aspects of the Red River of the North indicate that control of water pollution must be a cooperative effort, jointly administered by the States of North Dakota, Minnesota, and South Dakota. Steps in developing joint effort have been taken by these States in the official Tri-State Waters Commission and by an informal Interstate Sanitation Committee. The latter has established tentative waste treatment standards but enforcement is difficult under present arrangements. It appears that a suitable interstate agreement with necessary enforcement provisions might more successfully cope with the numerous water problems in the Red River of the North.

The planning of land and water resources development in the area has considered the various water uses. This outlook reflects a truly comprehensive viewpoint. Flow routing and regulation may benefit water supplies and improve stream conditions. The development program should provide wherever possible the desirable flow requirements specified in this report. If adequate water for dilution of treated wastes can be provided, possible annual benefits totaling $836,760 may accrue to the development program from savings in waste treatment plant construction and operation.

In the Red River Valley from Fargo-Moorhead to the International Boundary, large savings resulting from lower degrees of sewage treatment and lower operation and maintenance costs may be realized from increased, sustained, low flows. Benefits that may accrue from reuse of this dilution water by successive downstream communities and industries indicate possible economic justification of importing Missouri River water for this need alone.

CONCLUSIONS

1. Development of the land and water resources of the area will affect existing water distribution and related matters of water supply, public health, and sanitation.

2. Public and industrial water supplies may be benefited by the development program. Sources of supply may be provided where none now exist and present supplies may be improved in both quantity and quality.

3. Surface water resources receive pollution from numerous sources. All wastes should receive treatment prior to discharge to protect downstream water uses.

4. New waste treatment plants or improvements are needed at 85 municipalities and 74 industries.

5. It is possible for flow regulation, that provides sustained minimum flows adequate to permit assimilation of treated wastes, to result in considerable benefits accruing to the development project. These flows, in addition to water supply and stream sanitation benefits, will improve fish and wildlife habitat, enhance recreation and provide many intangible benefits.

6. The pollution control activities of the State water pollution control agencies have been commensurate with financial support and statutory backing. The excellent progress that has been made reflects the competency of the State Health Departments' personnel and the support and confidence of the public. Implications of a comprehensive water pollution control program, particularly where associated with water resources development, indicate need for active area-wide programs for pollution abatement with adequate funds and supporting legislation.

7. Solution of interstate water pollution problems in the Red River Valley may require an effective interstate agreement with satisfactory enforcement provisions, and possibly means for collecting funds to defray importation costs of water for public health and stream sanitation purposes.

8. The incorporation of water supply and public health needs in water resource evaluation is a necessary step in planning for the most beneficial uses of our natural assets. Support of the Bureau of Reclamation has made possible, at the present time, this cooperative investigation.

RECOMMENDATIONS

It is recommended that:

1. A comprehensive program for water pollution control in the Missouri-Souris Development Area be adopted by the State water pollution control agencies of Minnesota, Montana, North Dakota, South Dakota, and Wyoming.

2. The States of Montana, North Dakota, South Dakota, and Wyoming support their water pollution control agencies with effective water pollution control laws and with sufficient funds to permit maintenance of adequate staffs. Minnesota should continue its excellent support of its State water pollution control agency.

3. Adequate waste treatment as recommended in tables M-14, S-14, and R-14 be provided by the listed municipalities and industries.

4. State water pollution control activities be directed and intensified to secure installation of needed waste treatment works.

5. Wherever possible, the flow regulation program provide the useful desirable minimum flows as recommended in this report.

6. An effective interstate compact be entered into by the States bordering the Red River of the North to control interstate pollution problems.

7. A cooperative effort be exerted to establish means by which water may be secured for dilution of waste treatment plant effluents in the Sheyenne and Red River Valleys. This may include collection of funds for payment of such waters.

MISSOURI-SOURIS DEVELOPMENT AREA - GENERAL SECTION

TABLE OF CONTENTS

Page

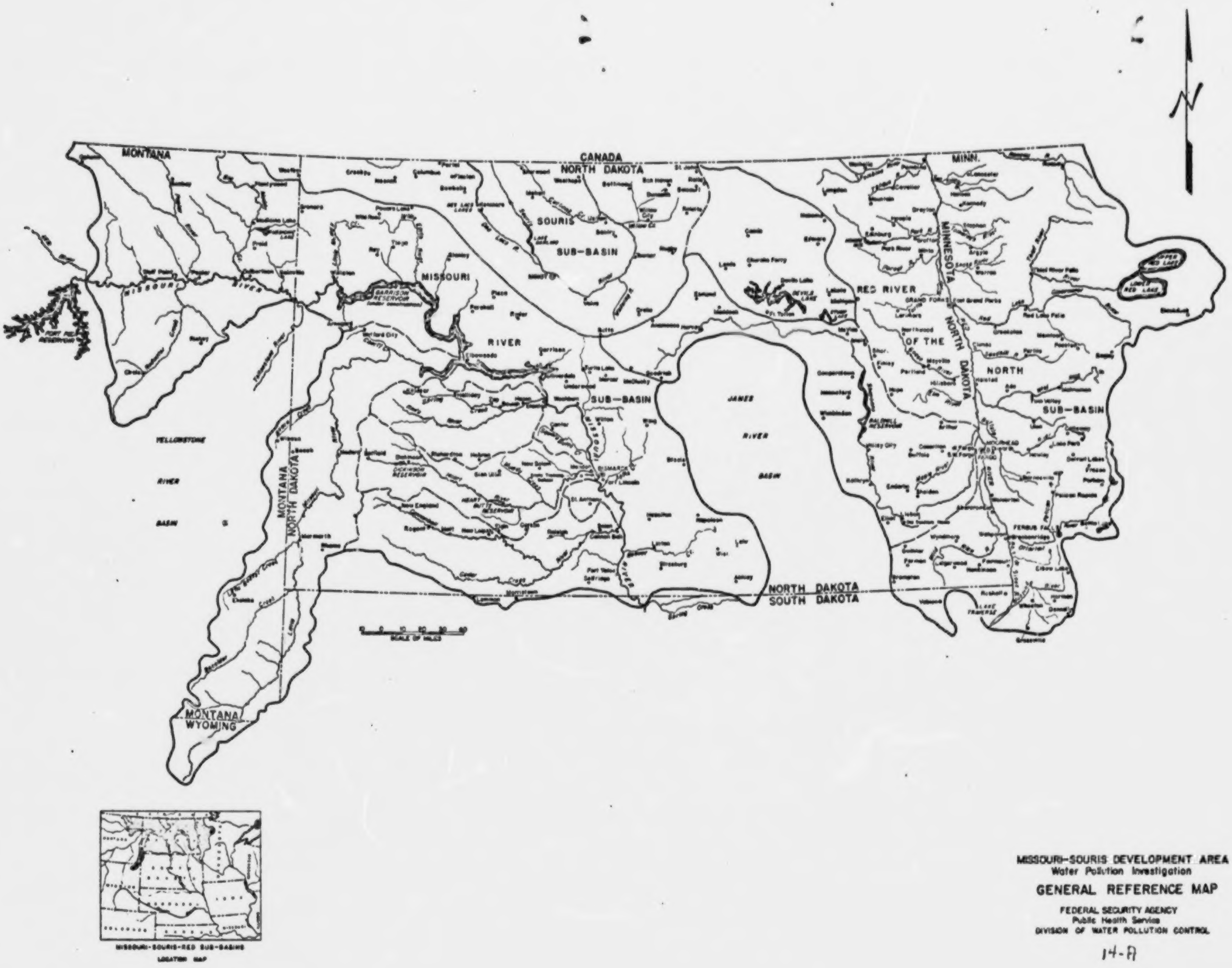
Historical Background 15
Physical Description 17
  Missouri River Sub-Basin 18
  Souris River Sub-Basin 21
  Red River Sub Basin 24
Economic Development 28
Survey Methods 29
  Field Investigations 29
  Laboratory Operations 31
  Definition of Terms 31
Use of Water Resources 32
  Land and Water Resources Program 32
  Water Supply 32
  Stream Sanitation 34
  Agriculture 34
  Hydroelectric Power 36
  Fish and Wildlife 36
  Recreation 36
Pollution Contributed to Water Resources 37
Damage to Water Resources from Pollution 39
  Public Health Aspects of Polluted Irrigation Waters . . . 39
Benefits Resulting from Pollution Prevention and Abatement . . 41
Pollution Prevention Measures in Effect 42
Review of State Water Pollution Control Laws 47
  Minnesota 47
  Montana 51
  North Dakota 54
  South Dakota 60
  Wyoming 64
Pollution Prevention Measures Required 68
Stream Flow Regulation and Sewage Treatment Requirements . . 75
  Benefits Attributable to Flow Regulation 75
  Sewage Treatment Requirements 77
  Evaluation of Flow Regulation 80
  Flow Requirements for Future Populations 80
  Dam and Reservoir Effect on Pollution Assimilation . . . 81

LIST OF TABLES AND FIGURES

Table		Page
1	Principal streams and their drainage areas	17
2	Stream characteristics	20
3	Agricultural statistics for 5-State area	28
4	Summary of development program dams	32
5	Summary of water supplies	33
6	Water use survey	35
7	Summary of sources of pollution	37
8	Industrial establishments surveyed	38
9	Bacterial efficiency of various sewage treatment processes	40

Figure		Page
1	General Reference Map	14
2	North Dakota Water Development Plan	18
3	Existing Primary Water Uses	32
4	Municipal and Industrial Water Supplies	34
5	Sources of Pollution	38
6	Pollution Abatement Needs	74

FIGURE 1


N
MONTANA
CANADA
NORTH DAKOTA
MINN.
MISSOURI
RIVER
SUB-BASIN
SOURIS
SUB-BASIN
RED RIVER
OF THE
NORTH
SUB-BASIN
JAMES
RIVER
BASIN
YELLOWSTONE
RIVER
BASIN
MINNESOTA
NORTH DAKOTA
MONTANA
NORTH DAKOTA
NORTH DAKOTA
SOUTH DAKOTA
MONTANA
WYOMING
GARRISON RESERVOIR
DICKINSON RESERVOIR
HEART BUTTE RESERVOIR
BISMARCK
GRAND FORKS
FERGUS FALLS
DEVILS LAKE
UPPER RED LAKE
LOWER RED LAKE
FORT PECK RESERVOIR
BALDHILL RESERVOIR
SCALE OF MILES
MISSOURI-SOURIS-RED SUB-BASINS
LOCATION MAP

MISSOURI-SOURIS DEVELOPMENT AREA
Water Pollution Investigation

GENERAL REFERENCE MAP

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

14-A

HISTORICAL BACKGROUND

The Missouri-Souris-Red Rivers domain is steeped in history interwoven with folklore. The origin of the name Missouri is lost in antiquity, although it is believed to have been the name of an Indian tribe which dwelt near the mouth of the "Big Muddy." Souris, the French word for "mouse," has led to occasional local use of the latter word for the name of the stream. Conceivably, the presence of large numbers of native field mice could have led to the name Souris. The name Red River is an English translation of the Chippewa name "miswagunmewesebee." The Chippawas were impressed by the vermillion hue the river acquired at sunset.

In general, streams of the region received their names from Indian association or descriptions of the locale such as: Bois de Sioux, Wild Rice, Goose, Sheyenne, Des Lacs, Popular, Beaver, and many others.

A strong belief exists among historians that a party of Swedish and Norwegian explorers under the distant command of the King of Sweden actually set foot in the Red River Basin in the year 1362. They allegedly landed at Hudson's Bay and worked their way inland on river craft. Recent studies strongly substantiate the belief that an inscribed tablet (the Kensington Stone) was prepared by these people.

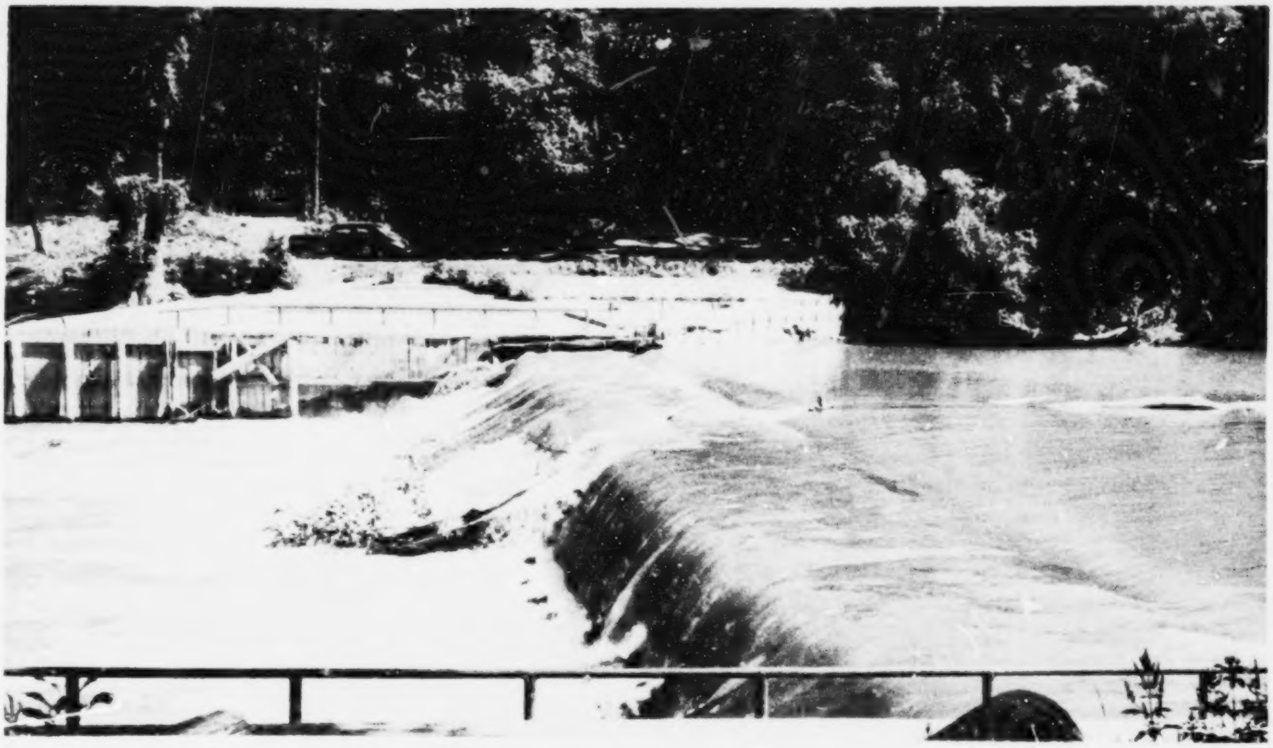
During the 17th century Sioux Indian tribes dominated the Red River Region and their influence extended westward into the Basin of the Missouri River.

Two bold Frenchmen, Radisson and Groseillers, arrived in the Red River Valley during the 1660's and became the first fur traders to penetrate its borders. They heralded the advent of a large and prosperous fur trade which lasted well into the latter half of the 19th century. Among early explorers, Pierre de la Verendrye stands out. His party explored and mapped much of the Red River and Missouri Basin. In 1738 he reached what is now Mandan, North Dakota, on the banks of the Missouri River, and visited with the legendary "white" savages at the village of the "Mantannes."

In 1803 the United States, by virtue of the Louisiana Purchase, gained title to the Missouri Basin. Lewis and Clark were dispatched in 1804 to explore and map the newly acquired territory. They traversed the Missouri River and wintered at the village of the "Mantannes."

The first agrarian settlers, under the auspices of Lord Selkirk, formed a community in 1812 at the confluence of the Pembina and Red Rivers. They were forerunners of an enormous agricultural industry. However, at the time of their settlement much animosity was displayed toward them by fur traders, who felt that agriculture and trapping were incompatible.

Establishment of territorial governments and passage of Homestead Laws during the middle of the 19th century proved catalytic in encouragement of mass immigration. The newcomers were largely farmers, who, despite hostile Indians, grasshopper plagues, wintry blizzards, drought,



Above: Riverside Park Dam, Red River, Grand Forks, North Dakota

Below: Red Lake River Dam, East Grand Forks, Minnesota

and flood, succeeded in their chosen work. During the early 1880's undeclared war raged against the Indian tribes and resulted in their complete submission. With the passing of the Indian wars and the admittance of the last of the territories in the region to Statehood the contemporary era was ushered in.

PHYSICAL DESCRIPTION

The area covered by this report encompasses several drainage areas linked together for maximum utilization of land and water resources. The plan proposes diversion of excess water from the Missouri River into the Souris Valley and possibly into the Sheyenne River, thence to the James River and back to the Missouri or via the Red River of the North to Hudson Bay (figure 2).

The Missouri-Souris Development Area, for purposes of this report, will include the Missouri River Sub-Basin from below the mouth of Milk River in Montana to Spring Creek, South Dakota, excluding the Yellowstone River Basin; the Souris River Sub-Basin in North Dakota, including Devils Lake area; and the Red River Sub-Basin south of the International Boundary (table 1). This area includes almost all the State of North Dakota, considerable portions of Minnesota and Montana, and small sections of South Dakota and Wyoming.

Table 1. Missouri-Souris Development Area - Principal streams and their drainage areas

Stream	Miles above mouth Missouri River	Drainage area square miles
Missouri River		49,700
Poplar River	1,775.8	3,270
Big Muddy Creek	1,725.7	2,870
Little Missouri River	1,506.8	9,500
Knife River	1,440.6	2,625
Heart River	1,373.3	3,400
Cannonball River	1,333.4	4,300
	Miles upstream International Boundary	
Souris River		8,862
Des Lacs River	242.5	
Wintering River	130.5	
Devils Lake Area	Landlocked	3,940
Red River		35,895
Bois de Sioux River	393.7	1,967
Ottertail River	393.7	2,048
Wild Rice River	315.2	2,210
Sheyenne River	272.3	7,380
Red Lake River	143.0	5,711
Pembina River	2.8	3,619

Missouri River Sub-Basin

This Sub-Basin drains approximately 49,700 square miles which are divided among four States as follows:

North Dakota - 32,560 square miles
Montana - 15,630 square miles
South Dakota - 800 square miles
Wyoming - 710 square miles

From Fort Peck Reservoir, Montana, the Missouri flows east for about 180 miles, enters North Dakota near Buford (approximately 70 miles south of the International Boundary), then turns in a generally southeasterly direction and leaves North Dakota south of Fort Yates at a point almost equidistant from the east-west boundaries of the State. The drainage area to the northeast is poorly defined and is separated from the James River and Hudson Bay drainages by an inconspicuous elevation. The largest tributary of the Missouri, the Yellowstone River, enters this section of the main stem.

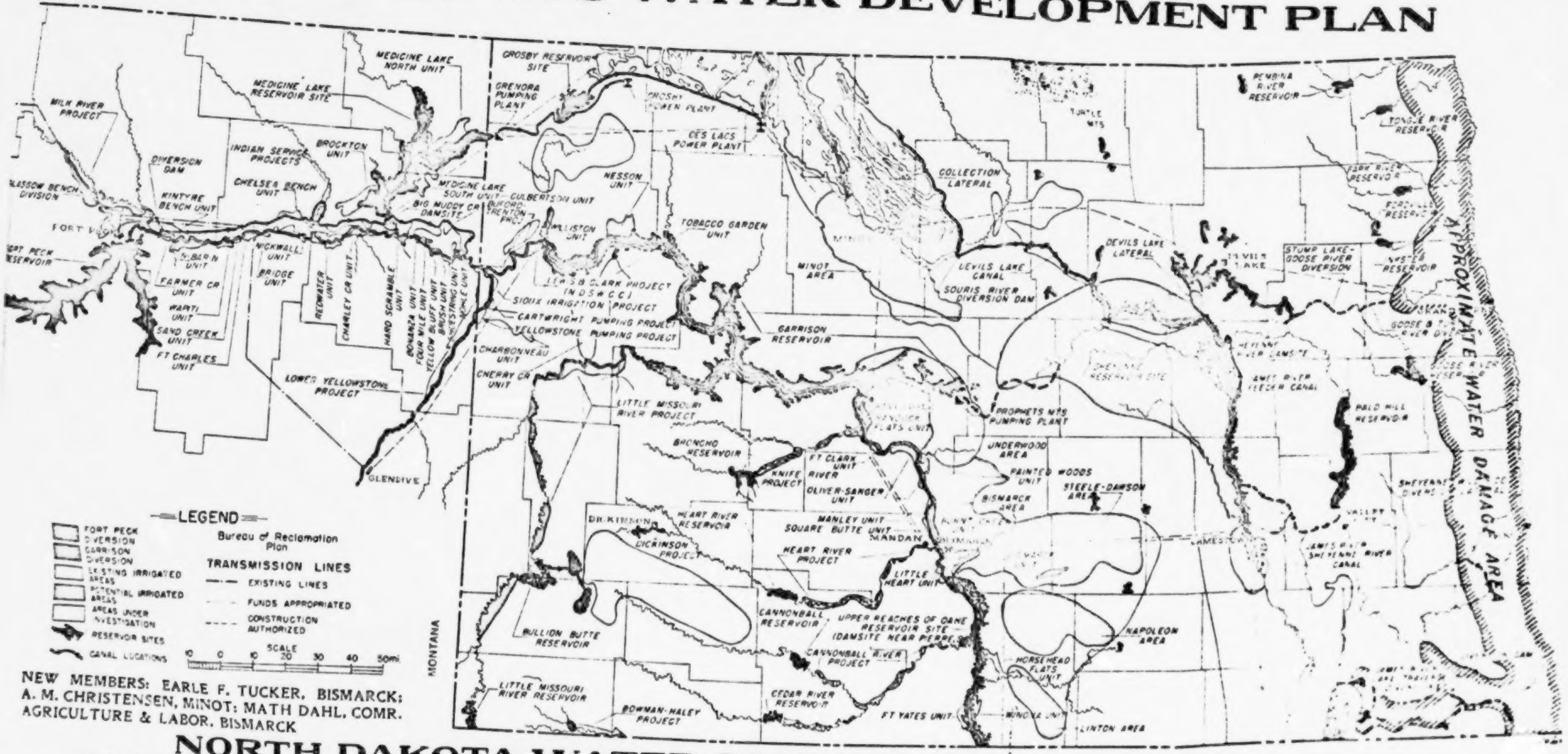
The Missouri and four principal tributaries, Little Missouri, Knife, Heart, and Cannonball Rivers that enter from the west, are all situated in the Missouri Plateau subdivision of the Great Plains province (figure 1). The Missouri Plateau consists of fairly smooth, rolling plains, local badlands areas, small "breaks" or rough broken land, and some mountains near the headwaters of the tributary streams. The slope of the main stem river bed is a little less than one foot per mile. Climate is fairly uniform throughout. The average annual rainfall amounts to about 16 inches with 70 to 75 percent occurring between April 1 and September 30. Average annual snowfall is about 30 inches. Length of growing season is approximately 115 days, with the period of May 21 to September 14 usually free of killing frosts. Long days permit rapid growth of crops during this short season. Average annual temperature is 40° F. and extremes of 110° and -47° F. have been recorded. The climate is classed as semiarid or subhumid, and is favorable to dry farming in all but extremely arid years. Elevations vary from 1,210 to 5,000 feet mean sea level.

Construction of Fort Peck Reservoir has altered the natural behavior of the Missouri for some distance below the dam and there is now relatively little spring overflow of bottom lands along much of the stretch considered in this report.

The Missouri has formed numerous oxbows through the rolling prairie of North Dakota, and many remnants of previous channels now exist as isolated lakes completely separated from the present channel. Curtailment of overflow in the spring by the river regulation program has robbed these lakes of a great portion of their water supply and they have diminished in size. Bottoms along this stretch of the Missouri are wooded, and marshy areas have developed around oxbow lakes.

It is in this region that the Missouri River receives the greater portion of its silt load. The Yellowstone River discharges an amount

NORTH DAKOTA'S WATER DEVELOPMENT PLAN

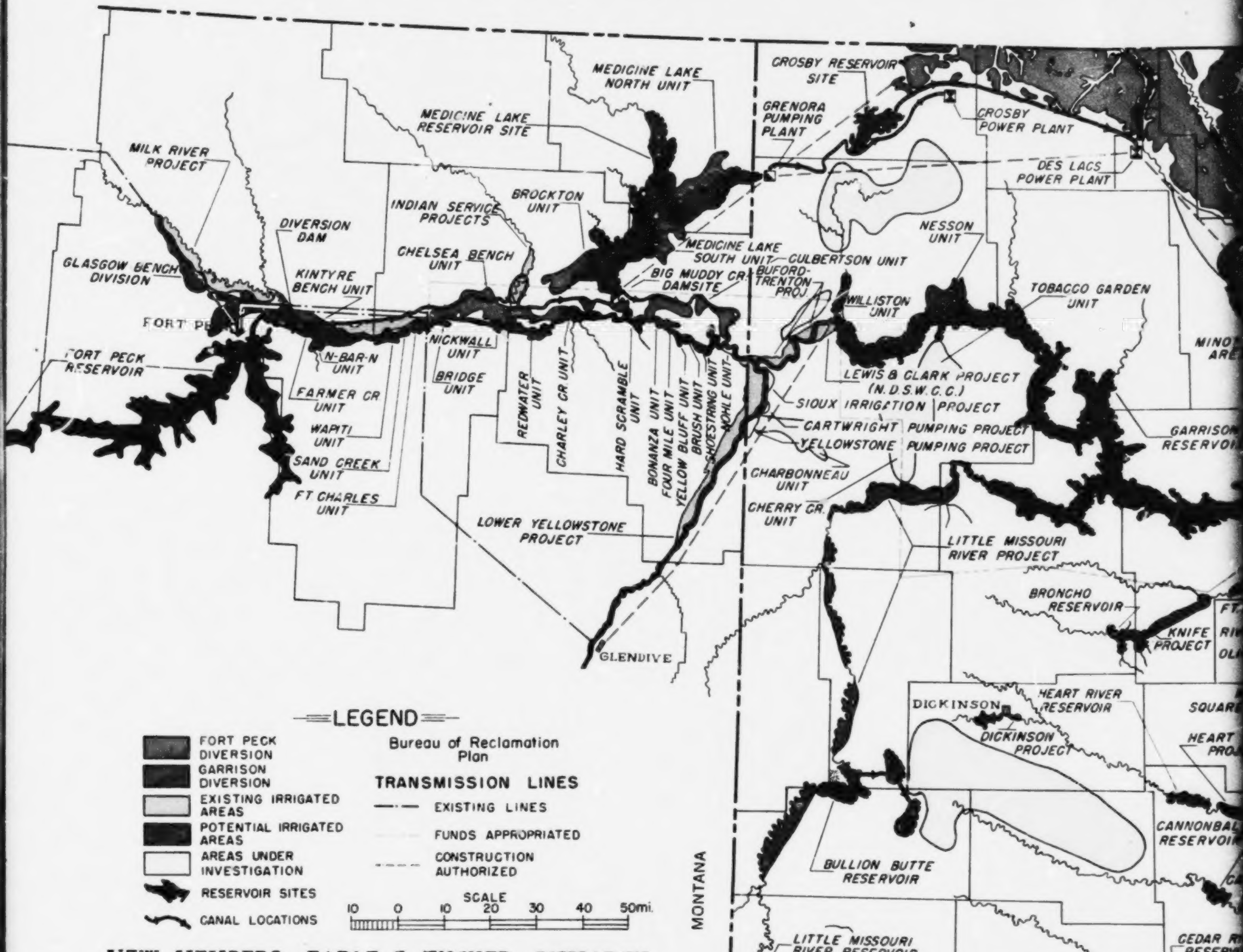

MILK RIVER PROJECT
GLASGOW BENCH DIVISION
FORT PECK
FORT PECK RESERVOIR
DIVERSION DAM
KINTYRE BENCH UNIT
MEDICINE LAKE RESERVOIR SITE
MEDICINE LAKE NORTH UNIT
INDIAN SERVICE PROJECTS
BROCKTON UNIT
CHELSEA BENCH UNIT
MEDICINE LAKE SOUTH UNIT
BIG MUDDY CR DAMSITE
CULBERTSON UNIT
BUFORD-TRENTON PROJ
WILLISTON UNIT
NICKWALL UNIT
BRIDGE UNIT
REDWATER UNIT
CHARLEY CR UNIT
HARD SCRAMBLE UNIT
BONANZA UNIT
FOUR MILE UNIT
YELLOW BLUFF UNIT
BRUSH UNIT
LIVESTRING UNIT
NOHLE UNIT
FARMER CR UNIT
WAPITI UNIT
SAND CREEK UNIT
FT CHARLES UNIT
LOWER YELLOWSTONE PROJECT
GLENDIVE
CROSBY RESERVOIR SITE
GRENORA PUMPING PLANT
CROSBY POWER PLANT
DES LACS POWER PLANT
NESSON UNIT
TOBACCO GARDEN UNIT
LEWIS & CLARK PROJECT (N D S & C C)
SIOUX IRRIGATION PROJECT
CARTWRIGHT PUMPING PROJECT
YELLOWSTONE PUMPING PROJECT
CHARBONNEAU UNIT
CHERRY CR UNIT
LITTLE MISSOURI RIVER PROJECT
BRONCHO RESERVOIR
GARRISON RESERVOIR
MINOT AREA
MINOT
COLLECTION LATERAL
DEVILS LAKE CANAL
SOURIS RIVER DIVERSION DAM
TURTLE MTS
DEVILS LAKE LATERAL
DEVILS LAKE
STUMP LAKE-GOOSE RIVER DIVERSION
PEMBINA RIVER RESERVOIR
TONGUE RIVER RESERVOIR
PARK RIVER RESERVOIR
FOREST RIVER RESERVOIR
SYSTER RESERVOIR
GOOSE RIVER DIV
GOOSE RIVER RESERVOIR
SHEYENNE RIVER DAMSITE
SHEYENNE RESERVOIR SITE
JAMES RIVER FEEDER CANAL
BALD HILL RESERVOIR
SHEYENNE RIVER DIVERSION
VALLEY CITY
JAMES RIVER SHEYENNE RIVER CANAL
JAMESTOWN
PROPHETS MTS PUMPING PLANT
UNDERWOOD AREA
PAINTED WOODS UNIT
STEELE-DAWSON AREA
BISMARCK AREA
BISMARCK
FT CLARK UNIT
KNIFE RIVER PROJECT
OLIVER-SANGER UNIT
MANLEY UNIT
SQUARE BUTTE UNIT
MANDAN
HEART RIVER PROJECT
LITTLE HEART UNIT
DICKINSON
DICKINSON PROJECT
HEART RIVER RESERVOIR
CANNONBALL RESERVOIR
UPPER REACHES OF OAHE RESERVOIR SITE (DAMSITE NEAR PIERRE)
CANNONBALL RIVER PROJECT
CEDAR RIVER RESERVOIR
FT YATES UNIT
BULLION BUTTE RESERVOIR
LITTLE MISSOURI RIVER RESERVOIR
BOWMAN-HALEY PROJECT
NAPOLEON AREA
HORSEHEAD FLATS UNIT
LINTON AREA
MONTANA
APPROXIMATE WATER DAMAGE AREA
LEGEND
FORT PECK DIVERSION
GARRISON DIVERSION
EXISTING IRRIGATED AREAS
POTENTIAL IRRIGATED AREAS
AREAS UNDER INVESTIGATION
RESERVOIR SITES
CANAL LOCATIONS
Bureau of Reclamation Plan
TRANSMISSION LINES
EXISTING LINES
FUNDS APPROPRIATED
CONSTRUCTION AUTHORIZED
SCALE
10 0 10 20 30 40 50mi

NEW MEMBERS: EARLE F. TUCKER, BISMARCK; A. M. CHRISTENSEN, MINOT; MATH DAHL, COMR. AGRICULTURE & LABOR, BISMARCK

NORTH DAKOTA WATER CONSERVATION COMMISSION

MEMBERS WATER COMMISSION: GOVERNOR FRED G. AANDAHL, EX-OFFICIO CHAIRMAN; ~~KENNETH W. SIMONS, BISMARCK~~, VICE-CHAIRMAN, SIVERT W. THOMPSON, DEVILS LAKE
EINAR H. DAHL, WATFORD CITY, CURTIS OLSON, VALLEY CITY, J. J. WALSH, BISMARCK, SEC. AND CHIEF ENGINEER, STATE ENGINEER

NORTH DAKOTA'S WATER


MILK RIVER PROJECT
GLASGOW BENCH DIVISION
DIVERSION DAM
KINTYRE BENCH UNIT
FORT PE
FORT PECK RESERVOIR
N-BAR-N UNIT
FARMER CR. UNIT
WAPITI UNIT
SAND CREEK UNIT
FT. CHARLES UNIT
INDIAN SERVICE PROJECTS
CHELSEA BENCH UNIT
MEDICINE LAKE RESERVOIR SITE
BROCKTON UNIT
MEDICINE LAKE NORTH UNIT
MEDICINE LAKE SOUTH UNIT
BIG MUDDY CR. DAMSITE
NICKWALL UNIT
BRIDGE UNIT
REDWATER UNIT
CHARLEY CR. UNIT
HARD SCRAMBLE UNIT
BONANZA UNIT
FOUR MILE UNIT
YELLOW BLUFF UNIT
BRUSH UNIT
SHOESTRING UNIT
KOHLE UNIT
LOWER YELLOWSTONE PROJECT
GLENDIVE
CROSBY RESERVOIR SITE
GRENORA PUMPING PLANT
CROSBY POWER PLANT
DES LACS POWER PLANT
NESSON UNIT
CULBERTSON UNIT
BUFORD-TRENTON PROJ.
WILLISTON UNIT
TOBACCO GARDEN UNIT
MINOT ARE
LEWIS & CLARK PROJECT (N.D.S.W.C.C.)
SIOUX IRRIGATION PROJECT
CARTWRIGHT PUMPING PROJECT
YELLOWSTONE PUMPING PROJECT
GARRISON RESERVOI
CHARBONNEAU UNIT
CHERRY CR. UNIT
LITTLE MISSOURI RIVER PROJECT
BRONCHO RESERVOIR
KNIFE PROJECT
FT. RIV OL
DICKINSON
HEART RIVER RESERVOIR
DICKINSON PROJECT
SQUARE
HEART PROJ
CANNONBAL RESERVOI
BULLION BUTTE RESERVOIR
LITTLE MISSOURI RIVER RESERVOIR
BOWMAN-HALEY PROJECT
CEDAR R RESERVO
MONTANA
LEGEND
FORT PECK DIVERSION
GARRISON DIVERSION
EXISTING IRRIGATED AREAS
POTENTIAL IRRIGATED AREAS
AREAS UNDER INVESTIGATION
RESERVOIR SITES
CANAL LOCATIONS
Bureau of Reclamation Plan
TRANSMISSION LINES
EXISTING LINES
FUNDS APPROPRIATED
CONSTRUCTION AUTHORIZED
SCALE
10 0 10 20 30 40 50mi.

NEW MEMBERS: EARLE F. TUCKER, BISMARCK; A. M. CHRISTENSEN, MINOT; MATH DAHL, COMR. AGRICULTURE & LABOR, BISMARCK

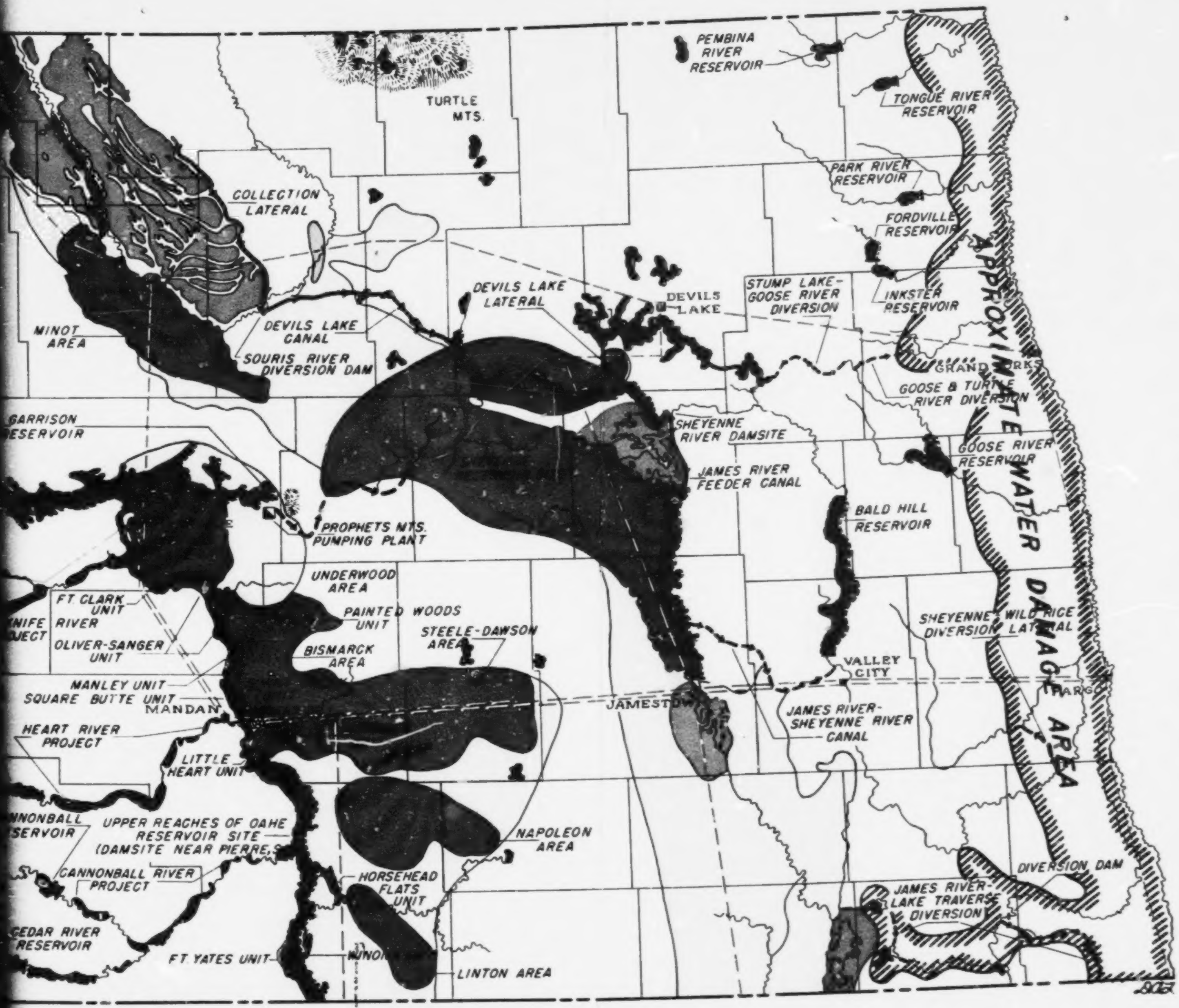
NORTH DAKOTA WATER CONS

MEMBERS WATER COMMISSION: GOVERNOR FRED G. AANDAHL, EX-OFFICIO CHAIRMAN; ~~[illegible]~~
EINAR H. DAHL, WATFORD CITY, CURTIS OLSON, VALLEY CITY, J. J. WAL

A

Figure 2

ER DEVELOPMENT PLAN



PEMBINA RIVER RESERVOIR
TURTLE MTS.
TONGUE RIVER RESERVOIR
PARK RIVER RESERVOIR
FORDVILLE RESERVOIR
COLLECTION LATERAL
INKSTER RESERVOIR
DEVILS LAKE LATERAL
DEVILS LAKE
STUMP LAKE-GOOSE RIVER DIVERSION
APPROXIMATE WATER DAMAGE AREA
MINOT AREA
DEVILS LAKE CANAL
SOURIS RIVER DIVERSION DAM
GRAND FORKS
GOOSE & TURTLE RIVER DIVERSION
GARRISON RESERVOIR
SHEYENNE RIVER DAMSITE
GOOSE RIVER RESERVOIR
JAMES RIVER FEEDER CANAL
BALD HILL RESERVOIR
PROPHETS MTS. PUMPING PLANT
UNDERWOOD AREA
FT. CLARK UNIT
PAINTED WOODS UNIT
KNIFE RIVER PROJECT
SHEYENNE-WILD RICE DIVERSION LATERAL
STEELE-DAWSON AREA
OLIVER-SANGER UNIT
BISMARCK AREA
VALLEY CITY
MANLEY UNIT
FARGO
SQUARE BUTTE UNIT
MANDAN
JAMESTOWN
JAMES RIVER-SHEYENNE RIVER CANAL
HEART RIVER PROJECT
LITTLE HEART UNIT
CANNONBALL RESERVOIR
UPPER REACHES OF OAHE RESERVOIR SITE (DAMSITE NEAR PIERRE, S.D.)
NAPOLEON AREA
DIVERSION DAM
CANNONBALL RIVER PROJECT
HORSEHEAD FLATS UNIT
JAMES RIVER-LAKE TRAVERSE DIVERSION
CEDAR RIVER RESERVOIR
FT. YATES UNIT
LINTON AREA

NSERVATION COMMISSION

~~ENNETH W. SIMONS, BISMARCK~~, VICE-CHAIRMAN; SIVERT W. THOMPSON, DEVILS LAKE;
WALSH, BISMARCK, SEC. AND CHIEF ENGINEER, STATE ENGINEER

B

18-A

of silt that is roughly 24 percent of the load carried by the Missouri at Kansas City. The Little Missouri, Knife, Heart, and Cannonball Rivers also contribute considerable silt.

The following descriptions of the four major tributary streams are based upon information contained in reports by the Corps of Engineers, Bureau of Reclamation, U. S. Geological Survey, and Fish and Wildlife Service.

Little Missouri River

The Basin of the Little Missouri is approximately 300 miles in length and averages about 40 miles wide. The river meanders through its valley and has a total length of 560 miles. The upper 90 percent of the Little Missouri courses through unglaciated regions consisting of terraces and local badlands. As it enters the glaciated region the river makes a sharp bend to the east, and then flows through a valley that has been gouged through an upland and which is totally lacking in terraces. From Alzada, Montana, to Camp Crook, South Dakota, the valley varies from 2 to 5 miles in width, but narrows above Camp Crook and averages only about three-fourths of a mile to Medora, North Dakota. In the glaciated region, valley width is from one-fourth to three-fourths mile. In its headwaters the stream is surrounded by a semi-arid, mountainous region, but develops a narrow flood plain from Alzada to Camp Crook that is bordered by a series of terraces receding from the river to the bluff line. The river flows through rather picturesque badlands from the southern boundary of North Dakota to near its mouth.

Stream discharge data are given in table 2-A. Two high stages normally occur each year--in March and April and again in June and July--the usual annual maxima are below 10,000 second-feet. Periods of low flow are usually in fall and winter when the discharge falls well below 100 second-feet, and at times below 10 second-feet. The silt concentration of the Little Missouri is high and has been estimated by the Corps of Engineers as twice that of the Missouri River at Kansas City. The grade of suspended particles is finer than that occurring in the Missouri River and much suspended silt must be colloidal in size. From September 1929 to July 1931 the ratio of total sediment discharge to water discharge was 1 to 131, or 7,630 parts per million by weight. Badlands are easily eroded and major differences in water discharge occasion great variation in rate of erosion. The stream bed is largely composed of sandy materials and is quite unstable. At lower stages the stream consists of pools and riffles and long flat areas.

Knife River

The Knife River appears to be similar to the Little Missouri in a number of characteristics. It flows through rolling plains and occasional local badlands, but its silt load is considerably less than that of the Little Missouri. The river meanders in a valley that averages about one-half mile in width. Many bends have cut-banks 100 feet or more in height. Flow is irregular and varies between wide

Table 2 - Missouri-Souris Development Area - Stream characteristics*

A. Missouri River Sub-Basin

	Main Stem Missouri River	Little Missouri River	Knife River	Heart River	Cannonball River
Stream length	-	560 mi.	165 mi.	241 mi.	295 mi.
Slope feet per mile	0.76'	4.6'	5.7'	4.9'	5.04'
Gaging station area drained	Bismarck, N. D. 186,360 sq.mi.	Watford City, N.D. 8,490 sq. mi.	Hazen, N.D. 2,352 sq. mi.	Mandan, N. D. 3,362 sq. mi.	Breien, N. D. 4,066 sq. mi.
Average discharge, sec.-ft.	25,250[a]	665	209	292	277
Maximum discharge, sec.-ft.	282,000	110,000	26,500	30,500	94,800
Minimum discharge, sec.-ft.	1,800	0	0	0	0
Stream bed	Medium sand	Medium sand	Medium sand	Medium sand	Medium sand
Average silt load ppm.	-	7,630	1,960	424	3[illegible]
pH	-	7.2 - 8.7	7.6 - 8.6	7.7 - 8.8	7.7 - 8.4
Iron ppm.	-	0.0 - 0.7	0.01 - 0.25	0.0 - 0.17	0.08 - 0.28
Calcium ppm.	-	28 - 88	30 - 66	22 - 78	18 - 75
Magnesium ppm.	-	9.2 - 40	11 - 39	12 - 52	24 - 40
Sodium and potassium ppm.	-	67 - 354	57 - 425	239 - 437	150 - 299
Bicarbonate ppm.	-	121 - 383	186 - 700	409 - 743	329 - 492
Sulfate ppm.	-	230 - 711	99 - 568	360 - 596	211 - 403
Chloride ppm.	-	1.0 - 9.3	0.9 - 12	2.8 - 32	5.6 - 14
Fluoride ppm.	-	0.3 - 0.6	0.3 - 0.9	0.4 - 0.8	0.3 - 0.5
Nitrate ppm.	-	0.0 - 6.0	0.4 - 3.0	0.4 - 4.3	0.5 - 2.0
Total hardness ppm.	-	116 - 380	128 - 313	104 - 406	186 - 327
Dissolved solids ppm.	-	499 - 1,350	346 - 1,420	944 - 1,420	701 - 1,000

B. Souris River Sub-Basin

	Souris River	Des Lacs River	Devils Lake
Stream length	360 mi.	-	-
Slope per mile	0.6'	-	-
Gaging station area drained	Westhope, N. D.	Foxholm, N. D.	-
Average discharge, sec.-ft.	162	46.6) 5 year	-
Maximum discharge, sec.-ft.	6,400	2,000) record	-
Minimum discharge, sec.-ft.	0	0)	
Stream bed	Mud, muck, gravel	Mud, muck, gravel	-
pH	8.0 - 8.3	7.8 - 8.5	7.4 - 8.8[b]
Iron ppm.	0.05 - 0.2	0.1 - 0.4	0.02 - 0.4[b]
Calcium ppm.	63 - 77	54 - 68	16 - 156[b]
Magnesium ppm.	29 - 45	30 - 36	95 - 6,160[b]
Sodium and potassium ppm.	126 - 228	240 - 352	472 - 26,380[b]
Bicarbonate ppm.	499 - 524	495 - 682	252 - 1,890[b]
Sulfate ppm.	134 - 270	275 - 435	715 - 58,800[b]
Chloride ppm.	36 - 143	42 (3 records)	326 - 10,700[b]
Fluoride ppm.	0.5 - 0.6	0.4 - 0.5	0.1 - 4.6[b]
Nitrate ppm.	0.1 - 6.0	0.6 - 4.0	0.1 - 25[b]
Total Hardness ppm.	276 - 375	258 - 318	563 - 25,700[b]
Dissolved Solids ppm.	698 - 963	978 - 1,240	1,900 - 102,000[b]

C. Red River Sub-Basin[1]

	Red River	Bois de Sioux River	Ottertail River	Red Lake River	Pembina River
Stream length	394 mi.	34 mi.	200 mi.	196 mi.	275 mi.
Slope feet per mile	0.50	0.74	2.82	1.94	5.09
Gaging station area drained	Grand Forks, N.D. 26,160 sq. mi.	White Rock, S. D. 1,160 sq. mi.	Near Fergus Falls, Minn. 1,810 sq. mi.	Crookston, Minn. 5,329 sq. mi.	Neche, N.D. 3,080 sq.mi.
Average discharge, sec.-ft.	2,294	-	205	1,022	157
Maximum discharge, sec.-ft.	80,000	1,120	1,200	27,400	10,700
Minimum discharge, sec.-ft.	2.4	0	1.0	2.5	0
Stream bed	Mud, muck, sand	mud, muck	mud, muck	Mud, muck, sand	Muck, mud, sand

---

[a] Based on data from Missouri Basin Inter-Agency Committee Report "Adequacy of flows in the Missouri River" April 1951.

[b] Variation among 4 major lakes.

[1] Chemical data appear in appendix F.

* Consolidated from numerous sources.

limits as does discharge of sediment. The river bed is of medium sand, slightly coarser than that of the Missouri River.

Heart River

The Heart River flows through undulating plains and breaks, and is much less turbid than either the Little Missouri or Knife Rivers. Its valley is roughly one-half mile wide and the stream channel is 15 to 25 feet below the valley floor. Flow is irregular. Silt carried is of finer grade than that of the Missouri River, and the stream may be clear in late summer, fall, and winter. Bottom sediments, although classed as medium sand, are of finer grade than those of the Missouri River.

Cannonball River

Although measurements are lacking it seems likely that the Cannonball River carries less silt than the other three since its course is through gently rolling uplands that are separated from the river valley by rather abrupt slopes. The river is normally clear in late summer, fall, and winter. Discharge data are given in table 2-A. Flows vary widely during the year; in 1950 variation was from 1,000 to 94,800 second-feet. The severity of floods is often magnified by ice jams at the junction of the Cannonball and Missouri Rivers. In winter months the flow is frequently reduced to zero.

Other Tributaries - Tributaries from the north and east are less significant than those entering from the west. In North Dakota the drainage area to the north and east is flat, contains numerous pot-hole lakes, and contributes little runoff. Streams entering below the Milk River in Montana--the Poplar, Big Muddy, White Earth, and Little Knife Rivers--drain badlands areas, and although little information concerning their characteristics is at hand, it may be assumed that they exhibit great variation in discharge and are fairly turbid. Discharge data for the North Dakota creeks are very scanty, but it appears that normally the majority of these streams cease to flow during dry periods of the year.

Souris River Sub-Basin

The Souris River is tributary to the Red River of the North. The Sub-Basin under consideration includes that portion of the Souris River drainage area in North Dakota, and the Devils Lake area, a landlocked region. Arising in the province of Saskatchewan, Canada, the Souris flows in a southeasterly direction and enters the United States about 15 miles northwest of Sherwood, North Dakota. The same course is followed to Velva, North Dakota, from where the river swings northeast to Towner, and then gradually assumes a northwest direction and re-enters Canada northeast of Westhope, North Dakota. The distance along the International Boundary between points of entry into and exit from the United States is about 47 miles. The loop of the Souris in the United States drains an area of approximately 8,862 square miles, or about 12 percent of the area of North Dakota.

The topography of the Souris Sub-Basin, due to deposit of glacial drift, varies from undulating to rolling to hilly. Underlying the

Above: Forest River near Minto,
North Dakota

Below: Sheyenne River near
Southwest Fargo
North Dakota

glacial drift is a bedrock of soft Pierre shale. Numerous meandering recessional moraines, extending in a generally southeasterly direction, occur within this drainage area, some being well defined while others have almost disappeared. Among these moraines are numerous small lakes and isolated drainage areas.

Above Minot, North Dakota, the valley of the Souris is straight with a rather uniform width of approximately one-half mile. The sides rise sharply to broad level benches about 100 feet above the river bed. From Minot to Verendrye the valley is somewhat wider and the overlying benches are lower and more broken. Downstream the benches become low ridges on the north side and the valley more or less merges with prairies extending to the Canadian Boundary. The river channel, about 100 feet in width, is tortuous. Total fall over a valley length of 170 miles and a channel length of 360 miles is slightly less than 200 feet. The steepest gradient, 1.7 feet per mile, occurs between Minot and Towner.

The Des Lacs River, the major tributary to the Souris in the United States lies in a valley quite similar to that of the Souris above Minot. Floods are rare in this valley but the general inundation they cause results in considerable damage to Minot and other towns and villages. Turtle Mountains rise slightly above the surrounding plain in the extreme northeastern part of the watershed.

A considerable portion of the water supply of the Souris River originates in Canada, and the river discharge is highly variable. Normally two high water periods, one due to melting of snow in the spring and the other to summer precipitation, occur each year. Much of the stream supply depends upon seepage from the soil; during the greater part of the year there is little or no surface runoff.

Devils Lake Area

Devils and Stump Lakes, from which there are no visible and no apparent subterranean outlets, partially drain an area of 3,940 square miles lying in a region that is roughly bounded by the Souris Valley to the west, the Sheyenne River to the south, the Red River of the North on the east, and the Canadian Border on the north. The term "partial" is used because the drainage system is poorly developed and a large portion of the total area contributes no run-off. The terrain surrounding the lakes varies from gently rolling to hilly and is strongly marked by glacial moraines. Numerous small lakes and ponds occur, and coulees are shallow and imperfectly developed. Soils are of glacial drift origin and consist of clay, sand, gravel, and boulders.

Climate in this area is rigorous. Winters are usually long and severe and summers may be quite hot. Records from the weather station at Devils Lake indicate a range in temperaturs from 112° F. to -46° F. The average January temperature is 3.7° F. and the average July temperature is 68° F. Average length of the growing season is 131 days, with the last killing frost usually occurring around May 15 and the first around September 3. Evaporation is considered to be about 32 inches per year and exceeds the average annual rainfall by about 15 inches.

Devils Lake was originally a single body of water, but is now divided into many separate lakes, the principal ones being Devils Lake and East Devils Lake. The smaller lakes were formed by isolation of small arms and bays. Since earliest definite records - 1867 - Devils Lake water levels have generally receded although some periods of slight increase have occurred. Historically, Devils Lake covered an extimated area of 86,000 acres and had an elevation of 1,433 feet mean sea level. In 1939 and 1940 the lake reached its lowest level of approximately 1,401 feet. In 1948 the water level rose 4 feet, at which point the lake covered an area of 7,000 acres. An outstanding water level rise occurred in 1950. The lake rose 8.3 feet to an elevation of 1,414.9 feet, the highest level since 1925. The surface area at this level is about 25,000 acres. During 1951 the lake level remained at approximately the latter height. No definite records regarding water level changes in Stump Lake are available but it is likely that the history of this lake is essentially the same as Devils Lake. In past years, receding water levels left an isthmus of dry land dividing original Stump Lake into two separate bodies of water. At present, they are separated by a county road fill. Table 2-B gives stream characteristics of the Souris River, Des Lacs River, and Devils Lake.

Before 1889, Mauvais Coulee, which drains an area lying to the north and northwest of Devils Lake, had a continuous flow and contributed considerably to the lake. This coulee has had little or no flow since then, except during periods of snow melt and excessive rainfall. Average annual precipitation is about 17 inches, mostly as rain during the growing season, but frequency and intensity of rains during normal years are insufficient to produce any appreciable runoff. Land use is probably the major cause of the diminishing runoff that has occurred. Practically all tillable soil is under cultivation causing rainfall during the growing season to be absorbed by the soil or lost through evaporation. The ground water table has been lowered by agricultural practices thereby lessening the amount of seepage entering the lake. The lowered water table and decreased runoff have also occasioned dimunition of smaller lakes (potholes) surrounding Devils and Stump Lakes.

Red River Sub-Basin

The Red River of the North, situated near the geographic center of the North American Continent, has a total drainage area at the International Boundary of 35,895 square miles, of which 16,065 square miles lie in North Dakota, 17,165 square miles in Minnesota, 670 square miles in South Dakota, and 1,995 square miles in Canada along the Upper Pembina River. The Roseau River at the Boundary drains 1,300 square miles in Minnesota and 370 square miles in Canada.

The Red River of the North is formed by junction of the Ottertail and Bois de Sioux Rivers at the twin cities of Wapehton, North Dakota, and Breckenridge, Minnesota. The distance from its source to the International Boundary is 394 river miles, which is almost twice the airline distance. The Red River flows almost due north and forms the boundary between North Dakota and Minnesota. The principal tributaries on the Minnesota side are the Ottertail, Buffalo, Wild Rice of Minnesota, Red Lake, Tamarack, and Two Rivers. Roseau River has its outlet to the Red of the North in Canada. On the North Dakota side the principal tributaries are the Wild Rice of North Dakota, Sheyenne, Goose, and Pembina Rivers.

The valley of the Red River above the International Boundary is a broad plain with a barely perceptible slope (two to three feet per mile in many localities) toward the river. This valley, or plain, flanked on the east and west by fairly steep slopes followed by higher upland areas, varies in width from 15 miles at the upper end of the valley to about 70 miles at the International Boundary. The flat land east of the river is lacking in natural drainage, and many areas on the upper portions of the Red Lake, Wild Rice, Two Rivers, and Roseau Rivers are unfit for agriculture. Stream characteristics are given in table 2-C.

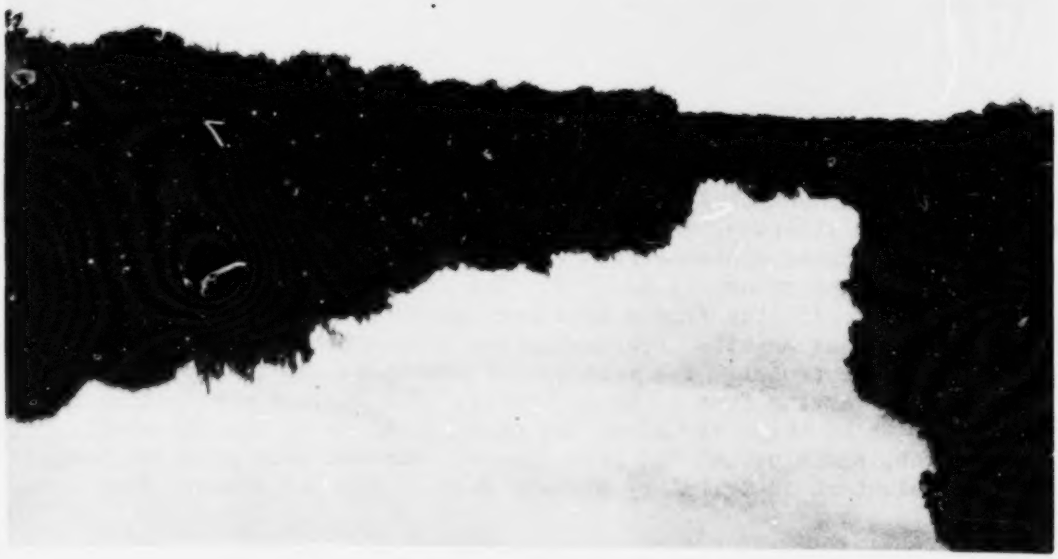
The slope of the river is from 980 feet above sea level at Lake Traverse to 789 at the International Boundary, or 0.48 feet per mile. The highest point in the drainage system is 1,850 feet mean sea level in Marshall County, South Dakota. The depression in which the Red River now lies was left by a Pleistocene glacier as it receded north. The valley sloped to the north and a lake, Lake Agassiz, was formed between the ice front and the natural barrier to the south. Lake Agassiz at first drained to the south through Lake Traverse, Big Stone Lake, and Minnesota River to the Mississippi; however the receding ice finally opened lower outlets to the north and drained all of the lake with the exception of the Manitoba lakes and Red Lake, which are remnants of Lake Agassiz. The lake level lowered in a series of stages leaving successive beaches and beach ridges formed by wave action.

Soils in the bed of Lake Agassiz are deep, heavy, finely-divided, well-compacted mixtures of clay, loam, and small portions of very fine sand. The greater portion of the lake bed is covered with a foot or more of black soil which was formed by decaying lake deposited organic matter. Properly drained, these soils are very fertile and are well suited to agricultural purposes. The Red River Valley is one of the greatest wheat producing regions of the nation. Soil above and east of the escarpment along the upper reaches of the tributaries is not so uniform but, with the exception of peat marshes, is suitable for development.

The climate of the Red River Basin is temperate with cold winters and warm summers. The prevailing winds are northwesterly. There is a geographical uniformity of climate throughout the area due to small variation in altitude. Summer temperature maximums range from 85° to 95° F. and winter minimums from -25° to -35° F. The mean annual temperature is approximately 38.7° F. The growing season varies from 103 to 139 days. Killing frosts have been known to occur as late as July, and as early as August. Ordinarily the frost-free period is from mid-May to mid-September. The mean annual precipitation is approximately 20 inches, varying from 16 to 24 inches. The maximum precipitation occurs east of the river along the upper portions of the Ottertail, Wild Rice, Buffalo, and Red Lake Rivers. Minimum precipitation occurs over headwaters of tributary streams west of the Red River. The

Left: Red River Valley drainage ditch near Northland, Minnesota

Below: Red River near Pembina, North Dakota



annual rate of evaporation at Grand Forks is 33 inches, and is estimated to vary from 24 to 36 inches over the Sub-Basin. Runoff amounts to one-half inch or less at the headwaters of the Sheyenne River, and 3 to 4 inches for Red Lake and Ottertail Rivers. Runoff of the entire Sub-Basin is only about 1.25 inches out of an average rainfall of 20 inches. Floods in the Red River Valley are normally caused by heavy precipitation over limited areas.

Lake Traverse, a long shallow depression, is the source of the Bois de Sioux River. It receives the greater portion of its supply from the Mustinka River on the east. Both Lake Traverse and Bois de Sioux River have become dry in periods of extreme drought such as prevailed in 1935. During periods of heavy runoff the Mustinka River formerly discharged enough water to flood land surrounding the lake up to White Rock, South Dakota, and beyond. Flow in the lake is now regulated by dams and gates which may provide more water for municipal and industrial purposes along the Bois de Sioux River. These works may also serve to better maintain the lake during droughts and to provide storage for flood waters.

Ottertail River is supplied by a large number of lakes above Fergus Falls making it one of the most uniform and best behaved streams in the Sub-Basin. Natural storage afforded by these lakes brings about regulation of flow. These lakes, 25 of them with controlled outlets, are the most popular recreational resorts in the area.

Red Lake River has its source in Red Lake. Red Lake has an area of 440 square miles; its discharge may be regulated.

The Roseau River has its outlet to the Red River in Manitoba, but the greatest part of the drainage area is in Minnesota. Much of its valley is flat and marshy, especially between Roseau Village and the International Boundary. The natural average fall below Roseau Lake is only 0.3 feet per mile. Floods are frequent and they cause heavy damage west of Roseau Lake. Flood waters, after leaving the channel of the Roseau River and flowing across level marsh, go on to the North and Middle Branches of Two Rivers, thus inundating valuable farm land 6 to 16 miles south of Roseau River.

The Sheyenne River heads in North Dakota in Sheridan County. It drains an area of 7,380 square miles. Spring runoff is great but later on the river is deficient or near zero in flow.

Wild Rice River of North Dakota drains an area of 2,210 square miles, of which 1,977 square miles lie in North Dakota and the remainder in South Dakota. The headwaters are in a typical drift prairie region, amid numerous sloughs and lakes. The lower one-third of the river lies in the Red River plain. The entire area is poorly drained allowing only a small part of the total precipitation to run off. Several sloughs and lakes along the Wild Rice River have been improved for waterfowl. More complete tributary descriptions, including Goose, Park, Pembina, and Forest Rivers, may be found under "Stream Conditions" of the Red River Sub-Basin Section.

ECONOMIC DEVELOPMENT

Agricultural pursuits and related activities are the basis of the region's economy. Data compiled from the 1940 census (table 3) indicate the high percentage of employed individuals used in farming. The principal farm income is from field crops and livestock. The "rural level-of-living index" in all States in the area is above that for the entire United States.

Table 3. Missouri-Souris Development Area - Agricultural statistics for 5-State area*

State	Percent employed in farming	Principal farm income: Crop	Principal farm income: Percent	Rural level-of-living index	Population per square mile
North Dakota	53.4	Field crops	52.9	108	9.2
Minnesota	30.3	Field crops	28.2	118	34.9
Montana	31.8	Field crops	41.9	113	4.1
South Dakota	48.1	Livestock	40.7	108	8.4
Wyoming	29.4	Livestock	55.5	117	2.6
U. S.	18.1	Field crops	31.6	101	44.2

*From County Data Book, Bureau of Census, U.S.Dept. of Commerce (1940).

Extensive prairies of the region support a large livestock industry. Wheat, corn, sugar beets, potatoes, and forage crops are also of considerable importance. Related food processing plants, flour mills, packing houses, creameries, sugar beet refineries, egg packing and poultry dressing establishments are located throughout the Basin. The development program designed to conserve water and land resources for maximum beneficial use will do much to improve the economy of the vital agricultural industry.

Transportation is a vital cog in the development of the area. Numerous Federal highways traversing the region, north-south and east-west, are supplemented by State and County systems. Several transcontinental railroad lines cross the region. Air lines service major communities.

Population growth within the Basin was steady until the decade 1920 to 1930, when Montana showed a minor reduction. From 1930 to 1940 the States of South and North Dakota lost portions of their population. All States except North Dakota showed population increases in the decade 1940 to 1950. Population per square mile for various States in the Basin is shown in table 3. Stabilization of farming economy by development of irrigation through the comprehensive development plan of the Missouri River Basin will do much to alleviate adverse effects of drought conditions.

SURVEY METHODS

Investigation of stream pollution in the Missouri-Souris Development Area involved three distinct areas: The Missouri River Sub-Basin, with large stream discharges in the main stem and highly variable flows in minor tributaries; the Souris River Sub-Basin, a region deficient in normal water resources; and the Red River Sub-Basin, with limited water resources and pollutional discharges from large cities and industries.

The investigation included:

(a) assembly and review of existing data and background information;
(b) procurement of most recent information regarding, (1) water supplies and water utilization and (2) sources of municipal and industrial pollution and treatment provided;
(c) institution of a sampling and laboratory program to secure various physical, chemical, bacteriological and biological information on stream conditions for use in correlating actual stream characteristics with sources of pollution. Laboratory data needed to properly evaluate pollutional effects on streams were obtained from two sampling periods, one during the critical summer season, and the other during conditions of ice cover in winter.
(d) review of proposed water routing for the purpose of determining which communities and river reaches may be affected by increased water resources;
(e) assembly and evaluation of data.

Field Investigations

Field surveys of water supplies and sources of pollution were conducted by sanitary engineers from state health departments and water pollution control agencies of Minnesota, Montana, North Dakota, South Dakota, and Wyoming; and the Public Health Service.

Water Supply

Water supply data collected for each municipality included: source of supply, treatment, population served, and average consumption. Industrial and agricultural uses of water were also considered.

Sources of Pollution

Domestic Sewage - For each municipality the data gathered included the sewered population, degree and type of treatment, and receiving body of water. The precentage B.O.D. removal by treatment plants was assumed to be 35 percent for primary treatment and 75 percent for secondary treatment where records or supplemental information were not available. The judgment and experience of the investigating engineer were depended upon to evaluate treatment processes where inspection indicated exceptionally good results, an overloaded plant, or inefficient or faulty operation.

Industrial Wastes - All industrial establishments discharging significant pollutional wastes were investigated; sufficient detail information was secured to permit a quantitative evaluation of organic pollution in terms of population equivalents. Survey data obtained from industries included the following information: type of industry, location, operation (with seasonal variation), water supply, quantity of raw materials, quantity of finished products, volume and characteristics of waste, degree of waste treatment, and receiving body of water.

Population Equivalent of Municipal Sewage - Organic industrial waste was expressed as population equivalents based upon B.O.D. Where industrial wastes were discharged to municipal sewers the population equivalent of industrial wastes was added to that of the sewered population. The waste discharged was the total population equivalent minus that portion removed by treatment.

Stream Evaluation

Sampling Procedure - Stream sampling stations were established above and below sources of known or suspected pollution, in the vicinity of dams or dam sites and diversions, at localities where other water uses might develop, and at appropriate points in or at the mouths of tributaries. In areas where significant pollution was expected intermediate points were added. Conveniently located bridges were utilized for sampling wherever possible. In the absence of bridges, suitable walk-in points were selected.

Sampling was conducted to secure a representative portion of the stream in question, generally at mid-depth from the main channel or channels. Generally, a copper depth sampler was employed, but a special pole-type sampler was used when conditions did not permit use of a depth sampler. For each sample the collector recorded the time of day to the nearest minute and the water temperature to the nearest degree centigrade. The sample collector also noted any unusual stream conditions, the presence of suspected sources of pollution, and other pertinent information. Samples were iced between times of collection and analysis. They were usually collected during the morning and transported to the laboratory with as little delay as possible.

Sampling Stations - A total of 12 sampling stations for chemical and bacteriological purposes were established in the Souris River Basin. The 11 main stem stations are located graphically in figures S-1 and S-2. One hundred and one samples were collected and 635 analyses completed.

In the Red River Sub-Basin 13 stations were established on the main stem and 12 at the mouths of principal tributaries. Locations of main stem sampling points are shown in figures R-1 and R-2. From these 25 sampling stations 153 samples were collected and 943 chemical and bacteriological analyses conducted. Sampling stations are described and their river mile location given in appendix F.

Stream Discharge - To correlate laboratory results with pollution reaching rivers, stream discharges must be secured at times of sampling. These data were obtained through the respective State agencies and the U. S. Geological Survey. Stream discharges are included with laboratory data in appendix F.

Biological Study - Biological investigations of the Red River were undertaken to establish the biological picture of the river and to ascertain the effects of pollutional wastes upon aquatic life. The study included chemical, physical, and biological analyses of stream samples. The presentation in subsections on "stream conditions" is based largely on biological investigation.

Biological samples consisting of two 6" x 6" Eckman dredge hauls from the bottom and one two-liter plankton sample were taken at Red River Stations 12, 11, 10, 9, 8, 7, H, 6, 4, 3, 2, and 1 during September 1950 and February 1951. Examination of these samples was according to the usual methods (Standard Methods for the Analysis of Water and Sewage, 9th Edition, 1946). Unfavorable weather conditions prevented winter biological studies on the Souris River, where a few plankton samples taken during the summer of 1950 represent the only biological data.

Laboratory Operations

Laboratory analyses were conducted by the State Health Department of North Dakota. Facilities utilized included the state laboratories at Bismarck and Grand Forks. A total of 1,578 individual analyses were made of 254 samples.

Laboratory Tests

Routine laboratory tests included temperature, turbidity, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, and coliform group organisms. Examination and analyses were made in accordance with "Standard Methods for the Examination of Water and Sewage" Ninth Edition, 1946, of the American Public Health Association.

A discussion of the significance of tests is presented in appendix G.

Definition of Terms

Definition of the following terms is given in appendix H: acre foot, cubic foot per second, population equivalent, (P.E.), parts per million (ppm.), plankton, benthos, periphyton, algae, and monocarbonate and bicarbonate alkalinity.

USES OF WATER RESOURCES

The region considered in this report is generally deficient in water resources. With exception of major rivers, stream flow is low and frequently approaches zero; most minor tributaries are intermittent streams. Ground water chemical quality is poor and local depletions have developed where withdrawals are in excess of recharge. This situation has led to extensive use of available surface waters (figure 3).

Land and Water Resources Development Program

A summary of the present development program dams is presented in table 4. Of a total of 15, 5 have been constructed, 2 are under construction, and 8 are potential. A detailed listing of the structures showing their locations by river miles and proposed uses is included in the Sub-Basin sections of the report.

Essentially, the development program is based upon conservation of Missouri River water for flood control, irrigation, power, municipal and industrial water supply, stream sanitation, and recreation. Fish and wildlife losses are to be prevented. Water from the bountiful Missouri will be pumped over the divide into the Souris, James, and Red River Basins for utilization in those areas. A detailed review of these developments is presented in the Sub-Basin sections.

Table 4. Missouri-Souris Development Area - Summary of development program dams[1]

Sub-Basin	Number of dams	Existing	Under construction	Potential
Missouri River	8	3	1	4
Souris River	1	-	-	1
Red River	6	2	1	3
Total	15	5	2	8

[1] Data from Bureau of Reclamation.

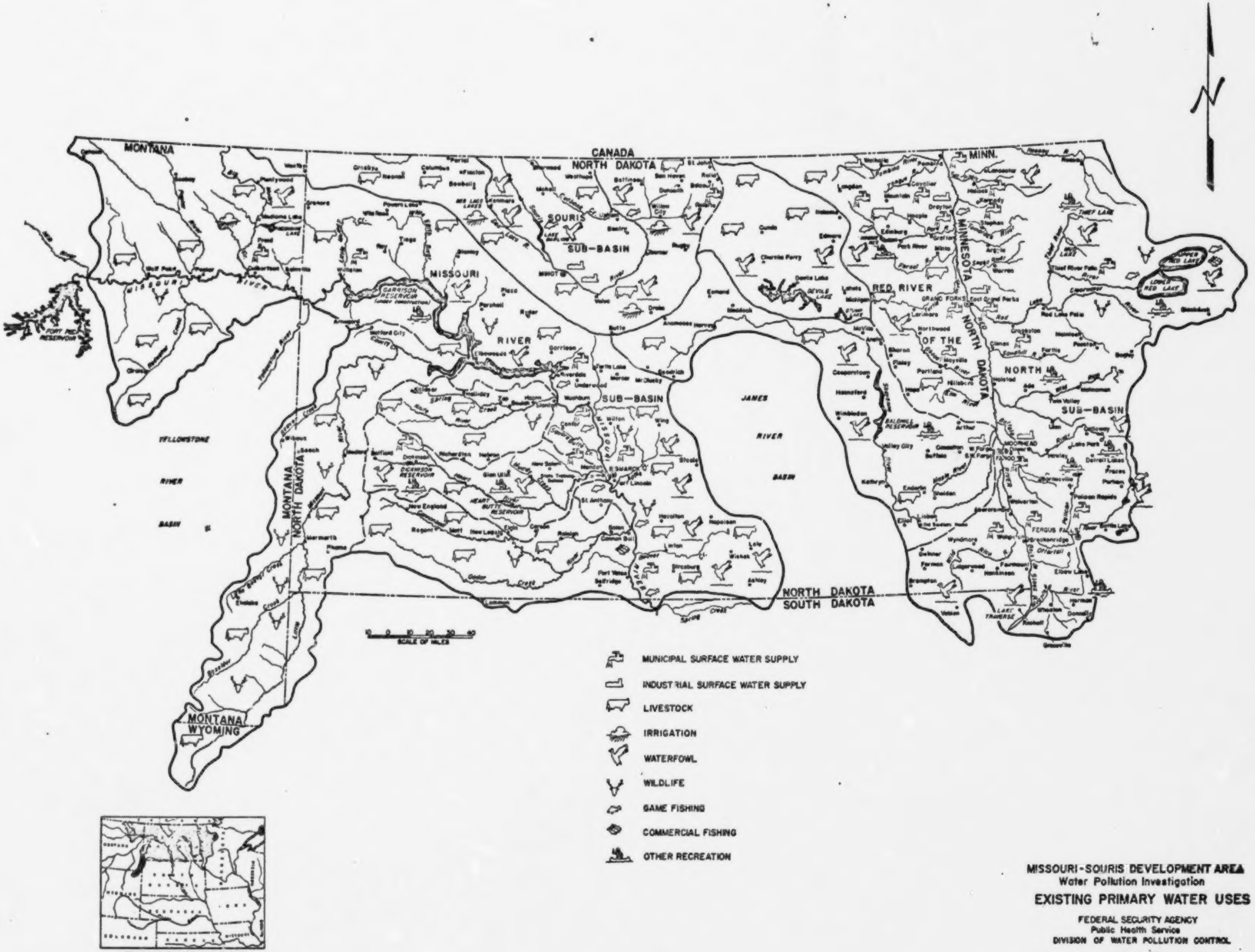
Water Supply

Municipal

Surface water supplies are used by 25 communities servicing 146,580 people and those industries connected to the municipal systems. Average daily consumption is 14.8 million gallons or slightly in excess of 100 gallons per capita. Surface supplies are generally coagulated, filtered, and chlorinated. Summary data are shown in table 5 and figure 4; detailed information is presented in Sub-Basin sections.

One hundred and sixty-eight communities secure municipal supplies from ground sources. A population of 153,210 utilizes an

FIG. NO. 8


CANADA
MONTANA
NORTH DAKOTA
MINN.
SOURIS SUB-BASIN
MISSOURI RIVER SUB-BASIN
RED RIVER OF THE NORTH SUB-BASIN
MINNESOTA
NORTH DAKOTA
JAMES RIVER BASIN
YELLOWSTONE RIVER BASIN
MONTANA
NORTH DAKOTA
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
GARRISON RESERVOIR
DEVILS LAKE
UPPER RED LAKE
LOWER RED LAKE
BISMARCK
MINOT
GRAND FORKS
FARGO
MOORHEAD
FERGUS FALLS
FORT PECK RESERVOIR
SCALE OF MILES
10 0 10 20 30 40
MUNICIPAL SURFACE WATER SUPPLY
INDUSTRIAL SURFACE WATER SUPPLY
LIVESTOCK
IRRIGATION
WATERFOWL
WILDLIFE
GAME FISHING
COMMERCIAL FISHING
OTHER RECREATION
MISSOURI-SOURIS-RED SUB-BASINS
LOCATION MAP

MISSOURI-SOURIS DEVELOPMENT AREA
Water Pollution Investigation

EXISTING PRIMARY WATER USES

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

32.A

Table 5. Missouri-Souris Development Area - Summary of water supplies

	Municipal Water Supplies[1]						Industrial Water Supplies[2]			
	Surface			Ground			Surface		Ground	
Sub-Basin	No.	Population served	Consumption M.G.D.	No.	Population served	Consumption M.G.D.	No.	Consumption M.G.D.	No.	Consumption M.G.D.
Missouri River	8	42,700	4.045	49	36,370	2.720	0	0	20	0.528
Souris River	1	450	0.045	23	37,130	2.608	1[a]	0.540	12	0.617
Red River	16	103,430	10.738	96	79,710	5.181	7[a]	12.136	100	2.057
TOTAL	25	146,580	14.828	168	153,210	10.509	8	12.676	132	3.202

[1] Includes industries serviced by municipal systems.

[2] Those with separate systems.

[a] Not including two power plant cooling water uses.

average of 10.5 million gallons each day, or 70 gallons per capita. In smaller communities use of individual wells continues. Ground water supplies are generally used without treatment except in a few instances where chlorination, filtration, iron and manganese removal, softening or combinations of these methods are employed. The low per capita consumption of ground water reflects the relative scarcity of this resource.

Industrial

Industrial uses of water include processing, cooling, clean-up, and air conditioning. Large amounts of water are utilized in food processing industries as dairy, meat packing, poultry dressing, and beet sugar refining. Meat packing plants may use 6,000 gallons of water per ton of animal processed, and poultry dressing establishments may need 2,000 gallons for each 100 pounds live weight of birds handled. Its use for air conditioning is attaining widespread application. Growth of industry in the Basin has created a demand for adequate water supplies. It appears that the factor limiting economic growth may well be scarcity of water. Utmost conservation is urgent with possible supplementation by water from more favored areas. There are 8 industrial surface water supplies in the area furnishing 12.7 million gallons each day (table 5 and figure 4). Groundwater sources furnish 3.2 million gallons of water a day to 132 industries.

Stream Sanitation

Streams are utilized universally for dilution, removal, and ultimate disposal of sanitary and industrial wastes, thereby rendering a vital health and economic service to community and industry. However, overexploitation of a watercourse for this purpose may result in unsanitary conditions and adversely affect downstream uses when inadequately treated domestic and industrial wastes are discharged to a stream.

There are 275 users of streams for ultimate disposal of wastes (figure 5 and table 7). Of this number 165 are municipalities, the remainder industrial establishments.

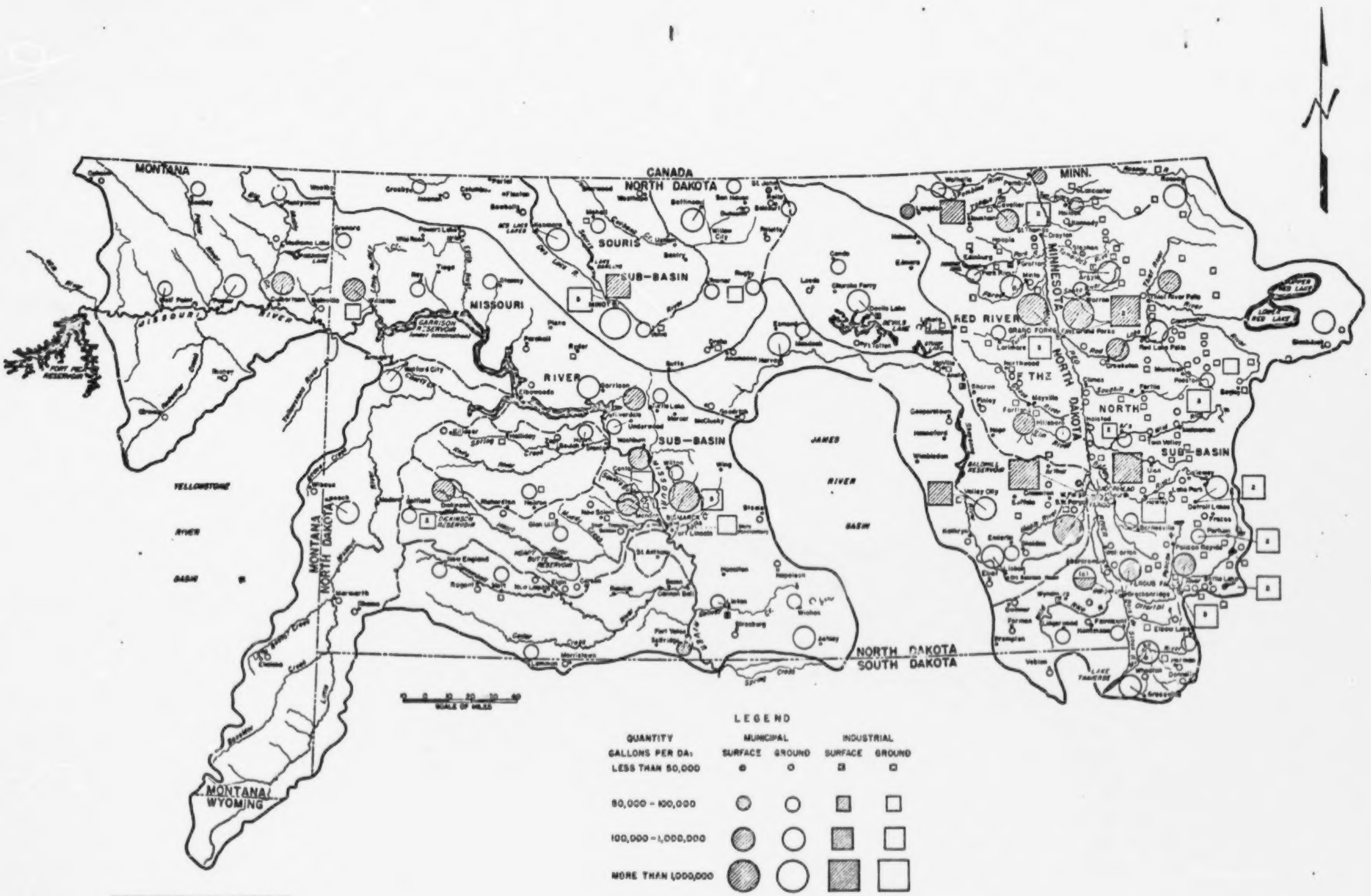
Agriculture

Irrigation

Irrigation has not been a major factor in development of agriculture in the region. Lack of water development, large areas that do not react favorably to irrigation, and areas where topographical features do not lend themselves to water application and drainage have tended to reduce the importance of this type of farm program. However, recent resource conservation developments, coupled with land classification, indicate extensive future irrigation possibilities in some sections of the area.

There are 40 irrigators in the Big Muddy Creek watershed and 9 in the Poplar River watershed in Montana, total acreage 3,600,

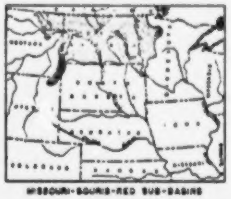
FIGURE 4


MONTANA
CANADA
NORTH DAKOTA
MINN.
SOURIS
SUB-BASIN
MISSOURI
RIVER
SUB-BASIN
RED RIVER
OF THE
NORTH
SUB-BASIN
MINNESOTA
NORTH DAKOTA
JAMES
RIVER
BASIN
YELLOWSTONE
RIVER
BASIN
MONTANA
NORTH DAKOTA
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
MISSOURI RIVER
GARRISON RESERVOIR
FORT PECK RESERVOIR
UPPER RED LAKE
LOWER RED LAKE
LAKE TRAVERSE
GRAND FORKS
BISMARCK
SCALE OF MILES
N

LEGEND

QUANTITY GALLONS PER DAY	MUNICIPAL SURFACE	MUNICIPAL GROUND	INDUSTRIAL SURFACE	INDUSTRIAL GROUND
LESS THAN 50,000	●	○	▨	□
50,000 - 100,000	●	○	▨	□
100,000 - 1,000,000	●	○	▨	□
MORE THAN 1,000,000	●	○	▨	□

NUMBERS WITHIN SYMBOL INDICATE NUMBER OF INDUSTRIAL SUPPLIES
(a) BOTH SURFACE AND GROUND SOURCE


MISSOURI-SOURIS-RED SUB-BASINS
LOCATION MAP

MISSOURI-SOURIS DEVELOPMENT AREA
Water Pollution Investigation

MUNICIPAL AND INDUSTRIAL WATER SUPPLIES

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

34-A

Table 6. Missouri-Souris Development Area - Water use survey[1]

Tributary	Irrigation			Industrial water supply		Municipal water supply		Flood control		Power			Wildlife refuges		Recreation			Stock watering and minor pools	
	Acreage	Annual diversion acre-feet	Annual return flow A-Ft.	No.	Cap'y A-ft.	No.	Cap'y A-ft.	No.	Cap'y A-ft.	No.	Head (ft)	Installed HP	No.	Cap'y A-ft.	No.	Natural area acres	Increase in area by control(A)	No.	Cap'y A-ft.
Big Muddy Creek	2,928	3,808	880	-	-	-	-	-	-	-	-	-	1	113,900	-	-	-	-	1,590
Poplar River	620	820	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	660
Total Missouri sub-basin	3,548	4,628	1,074	-	-	-	-	-	-	-	-	-	1	113,900	-	-	-	-	2,250
Souris River	9,539	13,490	3,494	3	Unk.	-	-	-	-	-	-	-	2	166,586	-	-	-	-	1,502
Long Creek	40	80	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	600
Short Creek	6	12	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	315
Des Lacs River	697	1,117	350	-	-	-	-	-	-	-	-	-	1	65,823	-	-	-	-	816
Wintering River	-	-	-	-	-	-	-	-	-	-	-	-	3	12,053	-	-	-	-	121
Willow Creek	-	-	-	-	-	-	-	-	-	-	-	-	6	24,135	-	-	-	-	1,846
Stone Creek	10	20	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86
Cut Bank Creek	45	90	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	959
Boundary Creek	180	360	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	166
Total Souris sub-basin	10,517	15,169	4,032	-	-	-	-	-	-	-	-	-	12	268,597	-	-	-	-	8,411[2]
Main Stem (Inc. Bois de Sioux and Lake Traverse)		-	-	-	-	5	3,930	1	112,500	-	-	-	-	-	1	-	-	96	555
Mustinka	-	-	-	-	-	1	small	-	-	-	-	-	-	-	1	-	200	-	-
Ottertail	-	-	-	-	-	3	1,450	-	-	6	214	8,225	1	32,060	30	72,885	5,642	-	-
N.D. Wild Rice	-	-	-	-	-	-	-	-	-	1	18	250	5	8,926	-	-	-	28	1,954
Sheyenne	-	-	-	4	172	2	1,300	-	-	-	-	-	14	14,301	-	-	-	305	10,828
Buffalo	-	-	-	-	-	-	-	-	-	-	-	-	1	300	3	1,734	173	-	-
Elm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	51
Minnesota Wild Rice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7,742	733	-	-
Goose	-	-	-	1	70	-	-	-	-	-	-	-	4	450	-	-	-	75	2,302
Sandhill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Lake	-	-	-	-	-	4	200	-	-	6	77	5,080	2	34,330	4	2,359	236	-	-
Turtle	-	-	-	1	small	-	-	-	-	-	-	-	1	195	-	-	-	121	492
Snake	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Forest	-	-	-	2	253	-	-	-	-	-	-	-	1	2,875	-	-	-	162	738
Park	-	-	-	-	-	1	small	-	-	-	-	-	1	216	-	-	-	189	964
Tamarack	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Two Rivers	-	-	-	-	-	1	small	-	-	-	-	-	-	-	1	740	74	-	-
Pembina	-	-	-	1	29	3	small	-	-	-	-	-	-	-	-	-	-	237	1,594
N.D.	- 1,570	3,140	1,101																
Minn.	- 2,800	5,600	1,960																
Total Red sub-basin	4,370	8,740	3,061	9	524	20	6,880	1	112,500	13	309	13,555	30	93,653	46	85,050	7,058	1,214	19,477

---

[1] Report on Water Use to the International Souris-Red Rivers Engineering Committee, Souris-Red Reference International Joint Commission, Revised Feb. 1950

[2] 2,000 dugouts with a capacity of 2,000 acre-feet included in total

(table 6). In the Souris River watershed, 32 water rights[1] dating from 1905 have been filed for irrigation use. Thirteen other recognized users do not have recorded water rights. Irrigated acreage in the Souris River watershed totals 10,500. Water right filings for irrigation in the North Dakota portion of the Red River watershed number 13; the area under irrigation totals 4,400 acres. These data do not include all irrigators but present a general indication of the extent of irrigation practice.

Livestock Watering

Extensive use is made of surface waters for livestock watering. In the Big Muddy Creek and Poplar River watersheds of the Missouri River Sub-Basin there are 2,250 acre-feet of stock-watering and minor capacity pools (table 6). The capacity of stock-watering impoundments in the Souris Valley is estimated at 8,411 acre-feet. In the Red River Valley 1,214 stock water and minor pools have capacity for impounding 19,477 acre-feet. Records are not complete for the entire area, yet the data presented show the general widespread use of stock water impoundments.

Hydroelectric Power

There are 13 hydroelectric power installations totaling 13,555 installed horsepower, all in the Red River Sub-Basin. Six are on the Ottertail River, Minnesota; 6 on Red Lake River, Minnesota; and 1 on the Wild Rice River, North Dakota. Hydroelectric power units will be included in Garrison Dam now under construction on the Missouri, and in potential Missouri Diversion Dam on the Missouri and Lonetree Dam on the Sheyenne. Two units, Crosby and Des Lacs power plants, are proposed in the Souris Sub-Basin.

Fish and Wildlife

Fishing varies from excellent in the Minnesota lakes to poor in most of the smaller streams. Many of the proposed impoundments may create improved fisheries. The area has a large wildlife population, particularly waterfowl. Numerous National Wildlife Refuges under the jurisdiction of the Fish and Wildlife Service have been established in the past, (table 6). One refuge includes 7 impoundments, totaling 113,900 acre-feet, in Big Muddy Creek Valley. The Souris Valley has 12 refuges (28 impoundments) with a total capacity of 268,597 acre-feet and the Devils Lake area has 5 totaling 18,978 acre-feet. The Red River Basin contains 30 refuge impoundments with 93,653 acre-feet capacity.

Recreation

Existing recreational facilities throughout the area, with the exception of the Minnesota portion, are quite limited. In the planning of proposed and existing multiple-use reservoirs, recreation has been an important factor. Dickinson Dam has provided excellent recreational developments, including boating, swimming, picnicking, and camping facilities. Similar developments have been made at Heart Butte, Baldhill, and Homme Dams. All proposed dams include recreation as one of their multiple uses. In the Minnesota portion of the area 46 recreation impoundments are located on tributary streams of the Red River of the North. Forty-five are natural basins with areas totaling 85,050 acres that have been increased 7,048 acres by outlet control works. The value of clean waters, a bubbling brook, and fish-abounding lakes, is being more and more recognized as an important factor in human well-being, emotional stability, and general happiness.

---

[1] Water Use Survey, Bureau of Reclamation, Jan. 1, 1950.

POLLUTION CONTRIBUTED TO WATER RESOURCES

Table 7 and figure 5 give summary data of sources of pollution. One hundred sixty-five municipalities, serving 312,020 people and industry discharging to municipal sewers, produce wastes having a population equivalent of 429,130. In addition, 110 separately discharging industries have organic wastes with a population equivalent of 134,450. The total waste load of 563,580 population equivalents is reduced about 40 percent through treatment leaving a population equivalent of 335,950 discharged to watercourses.

Table 7. Missouri-Souris Development Area - Summary of sources of pollution

	Municipal[1]		Industrial[3]		Total P. E.		Percent removal by treatment
Sub-Basin	No.	P.E.[2] un-treated	No.	P.E.[4] un-treated	Untreated	Dis-charged	
Missouri River	56	97,910	14	5,210	103,120	86,120	16.5
Souris River	19	66,100	11	4,010	70,110	43,570	37.9
Red River	90	265,120	85	125,230*	390,350*	206,260	47.2
Total Missouri-Souris Development Area	165	429,130	110	134,450	563,580	335,950	40.5

[1] Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

[2] Includes industrial wastes discharged into municipal sewerage systems.

[3] Industries having separate outlets.

[4] Organic wastes.

*Excluding population equivalents from two seasonal beet sugar plants.

Wastes from industries in this area are generally organic and may be treated in the same manner as domestic sewage. However, several sources of inorganic pollution were noted. Mine drainage waters are discharged in the Missouri and Souris Sub-Basins although the effects of these wastes do not appear to be extensive. Potato washers, principally in the Red River Valley, and a sand and gravel washer on the Souris River, contribute silt to the streams.

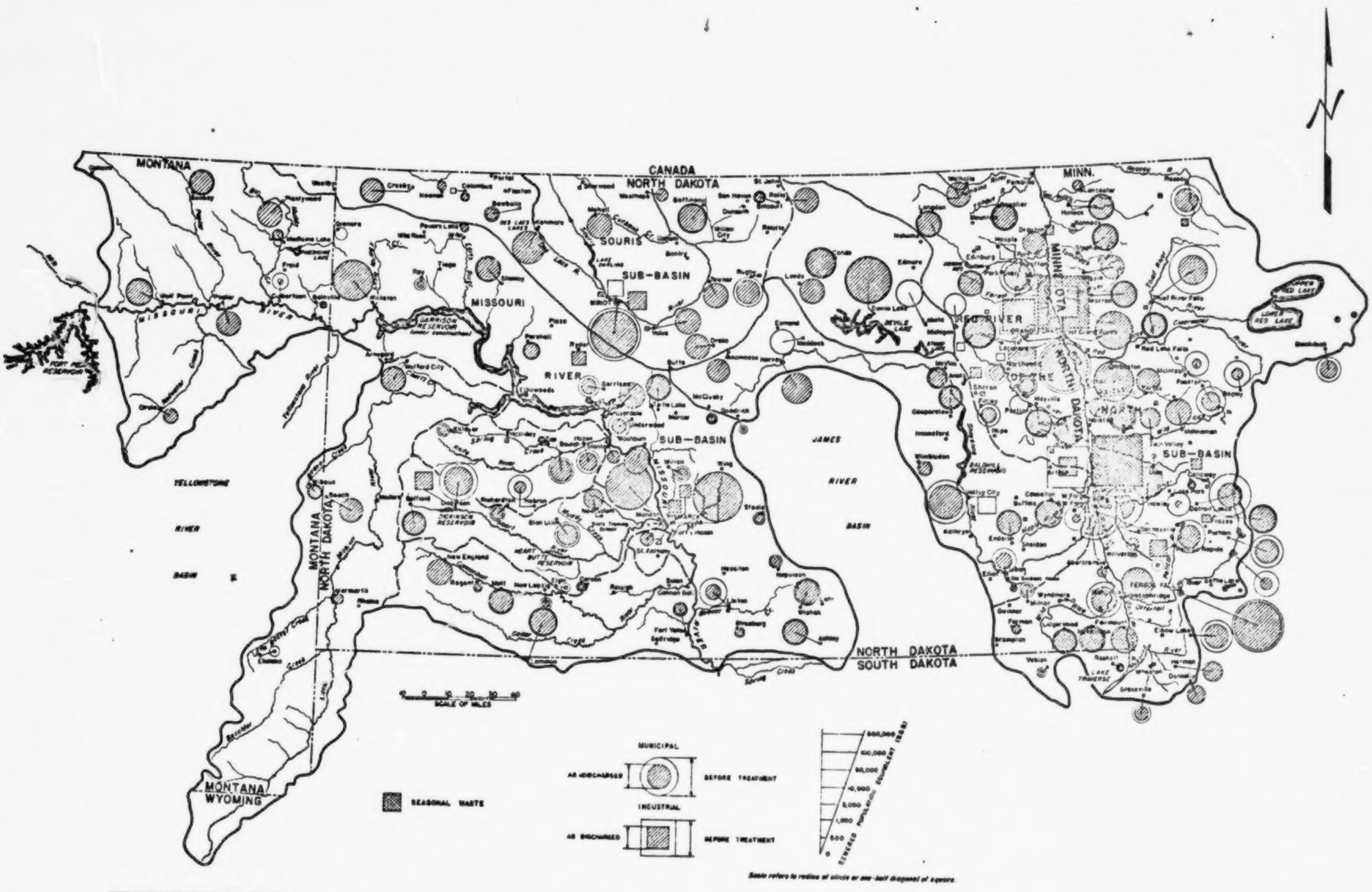
In this investigation 320 industrial establishments (table 8) were surveyed. About half of the industries visited were processors of dairy products while almost a third were associated with meat production. Potato washing and processing plants and sugar beet refineries were encountered in the Red Sub-Basin. Lignite mines are found in the Missouri and Souris Sub-Basins. Not all of the industrial establishments visited produced significant amounts of waste and many discharged to municipal sewers.

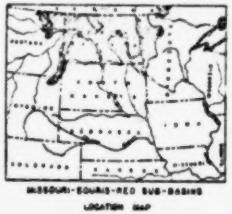
Table 8. Missouri-Souris Development Area - Industrial establishments surveyed

	Sub-Basin			
Industry	Missouri River	Souris River	Red River	Total
Dairy	26	20	108	154
Packing House	2	1	10	13
Slaughter House	7	14	26	47
Rendering	1	1	1	3
Stockyard	2	2	0	4
Poultry Dressing	5	6	12	23
Receiving Stations	1	7	1	9
Wheat Flour Mills	1	1	3	5
Potato Flour Mills	0	0	1	1
Potato Washers	0	0	15	15
Potato Chip	1	0	1	2
Hatchery	3	1	13	7
Egg Breaking	1	0	2	3
Railroad Shops	1	0	1	2
Coal Mines	3	3	0	6
Coal Processors	1	0	1	2
Sand and Gravel Washer	0	1	0	1
Bakery	1	4	1	6
Laundry	3	3	0	6
Brewery	0	0	1	1
Total	59	64	197	320

As may be noted in figure 5, the largest concentrations of waste discharges are in the Red River Valley. These wastes originate from both North Dakota and Minnesota and therefore are of interstate significance.

FIG. 13


CANADA
NORTH DAKOTA
MONTANA
MINN.
SOURIS
SUB-BASIN
MISSOURI
RIVER
SUB-BASIN
RED RIVER
OF THE
NORTH
SUB-BASIN
MINNESOTA
NORTH DAKOTA
JAMES
RIVER
BASIN
YELLOWSTONE
RIVER
BASIN
MONTANA
NORTH DAKOTA
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
GARRISON RESERVOIR
FORT PECK RESERVOIR
DEVILS LAKE
UPPER RED LAKE
LOWER RED LAKE
LAKE TRAVERSE
BALDHILL RESERVOIR
HEART BUTTE RESERVOIR
DICKINSON RESERVOIR
MINOT
10 0 10 20 30 40
SCALE OF MILES
SEASONAL WASTE
MUNICIPAL
AS DISCHARGED
BEFORE TREATMENT
INDUSTRIAL
AS DISCHARGED
BEFORE TREATMENT
500,000
100,000
50,000
10,000
5,000
1,000
500
0
SEWERED POPULATION EQUIVALENT (BOD)
Scale refers to radius of circle or one-half diagonal of square.


MISSOURI-SOURIS-RED SUB-BASINS
LOCATION MAP

MISSOURI-SOURIS DEVELOPMENT AREA
Water Pollution Investigation

SOURCES OF POLLUTION

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

38.7

DAMAGE TO WATER RESOURCES FROM POLLUTION

Discharge of untreated sewage and wastes to watercourses may create public health hazards, nuisances, and damage downstream water uses. Extent of damages that may be suffered are related directly to the downstream water use. These uses may be briefly summarized as follows: (1) sources of public water supply; (2) sanitation purposes in conveyance of sewage and industrial wastes after suitable treatment; (3) agricultural uses as irrigation and stock watering; (4) water supply for manufacturing and industrial purposes; (5) natural ice; (6) propagation of aquatic and wild game life; and (7) recreation.

Surface water shortages and poor quality of available ground water create an undesirable situation throughout this area, particularly in the Souris and Red River Sub-Basins. Pollution affecting surface waters will become more and more important as the need for water supplies increases. For example, Grand Forks, North Dakota, is equipped to obtain water from either the Red or Red Lake Rivers. It is reported that the dual system is necessary because the supply of water in the Red River has often been inadequate and sometimes so contaminated that treatment is difficult. Pollution generally makes treatment much more difficult and introduces possibilities of disease transmission.

Low stream discharges during drought years aggravated pollution conditions that resulted in lawsuits against several cities and industries by farmers and property owners living downstream. For example, in the fall of 1938 the City of Fargo was made defendant in two damage suits to the extent of $18,000 each.

There is a dearth of fishing and recreation areas and facilities in the major portion of the area under consideration. Because of this the value of suitable locations is greatly enhanced. Angling is practiced wherever suitable conditions prevail. The discharge of organic wastes if in sufficient quantities as related to stream flow will seriously depress or possibly deplete dissolved oxygen in the stream, making the environment untenable for fish life.

Public Health Aspects of Polluted Irrigation Waters

The comprehensive development plan of the Basin includes extensive irrigation projects. Significant public health problems arise with the use of sewage polluted irrigation waters. At the present time there does not exist a completely reliable yardstick for the measurement of these hazards under specific conditions. Although some health departments (appendix C) have promulgated standards, no single generally applicable standard, such as those available for drinking water, has been developed for the sanitary quality of irrigation waters. Appendix C contains a partial review of the literature of health hazards associated with irrigation which suggests that the use of polluted irrigation waters may be responsible for a number of diseases. An important consideration is the type of crop irrigated. Low-growing fruits and vegetables, such as celery, cabbage, carrots and strawberries, which are often consumed raw, offer the most serious hazard.

Possible hazards to livestock, particularly dairy cattle, must receive consideration. Farm water supplies may be adversely affected in some cases.

Irrigation with sewage polluted water has the effect of removing polluted water from points of only limited access, such as streams, and distributing the pollution over a much larger area where it may come into contact with fruit, vegetables, grains, and livestock, depending upon the local irrigation situation. The consequence in terms of the probability of the transfer of infectious material from a diseased host to a healthy person or animal must not be overlooked.

The sanitary survey--the locating of points of potential danger--is of great importance in any stream sanitation study. This report presents detailed information on the sources of pollution. Analyses of irrigation waters must be interpreted in the light of such survey findings. For example, the presence of coliform organisms in a headwater stream, even in large numbers, is less significant than when these same organisms are noted below a known sewer outfall. The time factor is of importance also. A small amount of pollution near the point of irrigation water use may, from a health standpoint, have much more significance than a much higher pollution load discharged into the stream a considerable distance away. This is true because bacterial contamination is rapidly reduced in a flowing stream. Storage in reservoirs generally has the effect of increasing the time of flow from a point above the reservoir to one below, thus contributing to the natural destruction of large numbers of bacteria.

Sewage treatment processes remove large numbers of bacteria, but the usual municipal sewage treatment plant is not designed nor operated to produce an effluent free from organisms pathogenic to man. Chlorination as a method of disinfection is employed to reduce the pathogenic organisms and total coliform count. Chlorination is not generally practiced at sewage treatment plants in the Basin. The same statement applies to the majority of sewage treatment plants in the United States. The approximate efficiency of various treatment processes as far as bacteria removal is concerned is shown in table 9.

Table 9. Missouri-Souris Development Area - Bacterial efficiency of various sewage treatment processes[1]

Type of treatment	Percent removal of bacteria
Primary treatment	25 - 75
With chlorination	90 - 95
Chemical precipitation treatment	40 - 80
Secondary treatment	
Complete trickling filter plant	90 - 95
Activated sludge plant	90 - 98
Intermittent sand filtration plant	95 - 98
Any of the above with chlorination	98 - 99

[1] Imhoff-Fair, Sewage Treatment, p 6 (John Wiley & Sons, 1940).

The preceding discussion has dealt with the more tangible public health aspects and damages from water pollution. Other aspects such as psychological well-being, although admittedly difficult to evaluate, are worthy of consideration. Healthful recreation can do much to safeguard physical, mental, and moral health. The resultant values, could they be properly evaluated, would certainly be high. Thus, pollution contributed to our streams damages many of these intangible values in addition to tangible items previously enumerated.

BENEFITS RESULTING FROM POLLUTION PREVENTION AND ABATEMENT

The Missouri-Souris Development Area is predominantly rural, with numerous small communities and few moderately-sized cities. It is only in the valley of the Red River, an interstate stream, that pollutional discharges are large and communities are close to each other. Elsewhere sources of pollution are light to moderate and usually are sufficiently separated to permit considerable stream recovery.

Benefits from pollution prevention and abatement involve protection to public water supplies and public health, prevention of nuisances, increased usability of downstream water, and enhancement of general welfare. Savings may result from reduced operational costs at downstream municipal and industrial water treatment plants. Fish and wildlife and recreational developments also derive direct benefits. The prevention or abatement of pollution may improve aquatic habitat and lead to increased incomes from development of recreational areas and sport fishing. Improvement in local fisheries and stream environment permits residents to enjoy recreational facilities without traveling to distant places.

The control of pollution will do much to protect the bacterial quality of waters used for irrigation, livestock watering, and ice harvesting. Another direct benefit is the enhancement of property values. It has been previously mentioned where property owners have brought suit against polluters for depreciating land values.

In an area where water resources are scarce and vital to the industrial and economical development. pollution control and abatement is essential to the continued expansion of the region's economy.

In addition to tangible benefits, there are many which are intangible. The value of an unpolluted stream for recreational pursuits is recognized as an important factor in the health and welfare of the people.

POLLUTION PREVENTION MEASURES IN EFFECT

The water pollution control agencies of States in this development area, despite limitations caused by lack of suitable legal authority, limited funds, or both, have good records in water pollution control. Municipalities in these States have shown a spirit of cooperativeness and an understanding of pollution control needs by installing numerous waste treatment plants. Further progress may be anticipated in the future. Industry has also cooperated, although more work remains to be done in evaluation of their wastes with regard to suitable conservation or treatment methods. In general, the area covered by this report is not heavily industrialized, except for the lower Red River, where considerable progress in industrial waste control and treatment has been made.

The Minnesota State Board of Health has long been active in the field of water pollution control. It has been supported by adequate law which, in 1945, was amended to form a comprehensive State Water Pollution Control Act with authority placed in a Water Pollution Control Commission. The Secretary and Executive Officer of the State Board of Health serves as Secretary of the Commission. The value of "clean waters" has been recognized by the people of Minnesota who know the importance of this natural resource as an attraction to sportsmen and tourists. It has been realized that the continuance of this valuable asset is contingent upon pollution control and abatement. Accordingly, the water pollution control agency has received full support, enabling it to maintain a competent staff of technical personnel, and has the respect of city officials, industry, and the citizens in general.

Of the total Minnesota population served by sewers, over 87 percent are tributary to some type of treatment. Approximately 65 percent of the sewered communities have sewage treatment. This compares very favorably with similar national statistics of 63 percent and 61 percent respectively. These figures reflect the activity of the water pollution control agency.

Montana has a good record in water pollution control. The State Board of Health enjoys the confidence of State, city, and industrial officials and the public at large, which has done much to aid the Board in pollution control and abatement. The principal weaknesses of its pollution control program have been inadequate statutory backing and insufficient State support to permit procurement and maintenance of an adequate staff of competent personnel. Both of these weaknesses should be corrected. In a State where water resources, although plentiful, are subject to high quality uses, and form a natural attraction for sportsmen and tourists--a thriving Montana industry--adequate support should be given to allow for full development of a comprehensive water pollution control program. The authority of the water pollution control agency should be broadened to encompass all water uses.

Twenty-nine percent of Montana's population served by sewerage is tributary to sewage treatment plants while 68 percent of sewered communities provide sewage treatment. This may be compared to national figures of 63 and 61 percent respectively. These figures indicate

7

that excellent progress in sewage treatment has been made by smaller communities, but that larger cities are lagging.

The North Dakota State Department of Health has long been active in pollution control and abatement, and considerable progress has been made. The Water Conservation Commission established in 1937 has been devoting its energies primarily to water appropriations and to broad phases of water resource development. The limited supply of good waters in many sections of the State of North Dakota has done much to focus attention on the need for pollution control and abatement. However, there is need for more adequate statutory support for the control of water pollution and for sufficient funds to provide the additional technical personnel necessary for carrying out the control program. It appears that legal support may be secured either by passage of a comprehensive water pollution control law or by the formulation of strong regulations by the Water Conservation Commission.

Of the population of North Dakota communities having sewerage, 83 percent are tributary to some form of treatment while 87 percent of the sewered communities provide treatment. These figures compare very favorably with national figures of 63 and 61 percent respectively and reflect the excellent progress in pollution control and abatement.

For many years South Dakota has been active in water pollution control and at present is conducting stream pollution investigations within the State in cooperation with other States. Approximately 82 percent of the population tributary to sewerage is served by treatment plants and 71 percent of the sewered communities treat their wastes. This compares with 63 percent and 61 percent, respectively, on a national basis. The statistics reflect the progress in pollution control. An increase in the educational activities of the water pollution control agency may prove beneficial. While existing State legislation is subject to certain defects, much has been and can be accomplished under current law. Hearings are excellent means to acquaint the public with the needs and benefits of pollution abatement.

The Wyoming State Department of Public Health is showing increased activity in water pollution control. Major investigations have recently been completed and others are contemplated within the limitations of available funds and personnel. The educational activities of the health department should be increased and intensified. Wyoming, being a tourist State offering a wide variety of recreational pursuits, must protect its vital natural resources. Accordingly, the State has considerable need for adequate treatment of sewage and industrial wastes. The State water pollution control agency should hold hearings to publicize these needs and to secure support for pollution abatement.

Only about 36 percent of the sewered population in the State are served by sewage treatment of some sort. The national average is about 63 percent. Less than half (43 percent) of those communities with sewer systems provide some type of sewage treatment as compared with the national average of 61 percent. There appears from these figures to be quite a fertile field for promotion of water pollution abatement activities among the cities and towns of Wyoming.

The States bordering the Red River Valley, cognizant of vital water resources of the river, undertook a cooperative approach to achieve uniform action on a problem of concern to all, and in 1938 formed a Tri-State Waters Commission. In recent years this commission has not been active. An appraisal of the water supply and waste disposal functions of the Tri-State Waters Commission in the Red River Basin as revealed by legislation establishing the Commission follows[1]:

"The States of South Dakota, North Dakota, and Minnesota, by formal agreement, executed with the specific authorization of their respective legislatures and approved by the Congress on April 2, 1938 (52 Stat. 150) entered into an interstate compact creating the Tri-State Waters Commission. The Tri-State Waters Commission was created as a corporation composed of nine commissioners, three from each State. The Commission is authorized to elect from its members a chairman and a vice-chairman, and is given the authority to appoint, and at its pleasure remove, an executive secretary and such other officers and assistants as may be required to carry out its functions. The Commission has jurisdiction with a district known as the Tri-State Waters Area, which comprises that portion of the Drainage Basin of the Red River of the North lying within the boundaries of Minnesota, South Dakota, and North Dakota.

The Commission is charged with the duty of:

1. Making recommendations for any legislative action deemed by it advisable to carry out the intent and purpose of the Interstate Compact;

2. Maintaining and controlling lake levels and stream flow on boundaries within the area. The Compact, however, specifically states that the Commission is to have no power or jurisdiction over water levels or stream flow in the Ottertail River and its chain of lakes and tributaries;

3. Studying the various water problems relating to water supply in the Tri-State Waters Area.

"Plans prepared by State, municipal and industrial agencies for 'works' on boundary waters in the Tri-State Waters Area are to receive the approval of the Commission before construction is begun.

"The Commission is also given the power to cooperate with any duly authorized Federal, State, or municipal agency in studies and surveys, construction, maintenance, and operation of 'water projects' within the scope of its jurisdiction. The Commission is authorized to exercise the power of eminent domain to acquire such real and personal property as may be necessary to effectuate its functions, and generally, to exercise in connection with property under its control, and other affairs in connection with its duties, all powers which may be exercised by a private corporation in connection with similar property and affairs.

---

[1] Prepared by Attorney Murray Stein, Office of the General Counsel, Office of the Administrator, Federal Security Agency.

"While the words 'works' and 'water projects' are not defined by the Compact and a definitive definition of such terms should probably, at least in the first instance, be attempted by the local authorities, it would seem likely that these terms include activities relating to water supply and waste disposal. Article 7 of the Compact specifically places a duty on the Commission to study water supply problems within the Tri-State Waters Area. It would seem that concern with water supply is a definite function of the Commission. Further, the title of Public Law 456, 75th Congress, which gave the consent of the Congress to this Compact, specifically states that it is:

> 'AN ACT consenting to an interstate compact between the States of Minnesota, South Dakota, and North Dakota, relating to the utilization of, the control of the floods of, and the prevention of the pollution of the waters of the Red River of the North and streams tributary thereto.' (Underscoring supplied.)

"The Act was specifically amended to mention utilization and prevention of pollution of the waters of the Red River of the North and streams tributary thereto by the Congress (Vol. 83, Cong. Record, Part 4, pages 3835-3837), as the bill originally had a simpler title which did not specifically mention these functions. This original title, which was amended, follows:

> 'AN ACT granting the consent of Congress to compacts or agreements between the States of Minnesota, South Dakota, and North Dakota with respect to the Red River of the North.' - Cong. Record, Vol. 83, Part 4, page 3775."

To further aid pollution control in the Basin, the Departments of Health of the States of North Dakota, South Dakota, and Minnesota, the North Dakota Water Conservation Commission, the Minnesota Department of Conservation, and the South Dakota agency concerned with water conservation, formed an informal Red River Drainage Basin Interstate Sanitation Committee in 1944 to ". . . . . proceed with such studies and investigations as shall be necessary to determine the nature, degree, causes, and sources of pollution, and shall recommend plans and methods for interstate cooperation on the part of said States in dealing with pollution problems in the drainage basin of said river and for action by the proper authorities in specific cases involving such pollution." This Committee has been and still is active and has done much to point up the pollution problem in the Red River Valley. It has cooperated effectively with Federal agencies in the water conservation and development program.

In 1949, the Committee adopted "Standards of Treatment for Municipal and Industrial Wastes for the Red River of the North"; the formal text of which follows:

"The following previously adopted standards on stream pollution control are hereby confirmed and clarified, and recommended for use under ordinary conditions as a basis for the review of plans prepared and submitted to the regulatory agencies of the respective States for sewage and waste treatment facilities discharging into the

Red River of the North and the tributaries as they affect the Red River of the North.

"It is recommended that industry and municipalities treat their wastes to the point where the average daily composite 20° C., 5-day B.O.D. is 25 ppm., suspended solids 30 ppm., with no peaks running over 50 ppm. 20° C., 5-day B.O.D. and 60 ppm. suspended solids. Chlorination shall not be used as means of obtaining the B.O.D. reductions, although it may be required for other purposes. Certain types of industrial wastes, such as those resulting from the processing of agricultural products, may have to be considered on an entirely different basis.

"It is further recommended that these standards be considered as general only, and that they be subject to modification to meet specific pollutional problems as they develop."

These standards were later adopted by the respective State regulatory agencies. The standards essentially establish the principle of secondary treatment for all organic wastes discharging to the Red River or to tributaries where they have an appreciable effect on the Red River.

REVIEW OF STATE WATER POLLUTION CONTROL LAWS[1]

In accordance with the provisions of the "Memorandum of Understanding," appendix A, a review of laws pertaining to water pollution in effect in the States of Minnesota, Montana, North Dakota, South Dakota, and Wyoming, is presented. Appendix B contains a suggested State water pollution control act and explanatory statement[2].

Minnesota

I. General Statement

In 1945 Minnesota enacted a comprehensive State Water Pollution Control Act with authority vested in a Water Pollution Control Commission. The State Board of Health also has certain water pollution control functions relating to public health and sources of water supply for domestic use. Statutory authority of the Board of Health relating to water pollution has existed for more than 65 years and was last amended in 1945.

As the Water Pollution Control Commission has been given the power and duty of administering all laws relating to the pollution of any waters of the State, the Surgeon General has designated it as the State water pollution agency pursuant to the Federal Water Pollution Control Act.

Minnesota statutes relating to water pollution are found in Minn. Stat. Ann. 144.34-144.38.

II. Administrative Organization

An independent Water Pollution Control Commission consisting of the Secretary and Executive Officer of the State Board of Health, the Commissioner of Conservation, the Commissioner of Agriculture, Dairy and Food, the Secretary and Executive Officer of the State Livestock Sanitary Board, and three members at large representing municipalities, industries, and general interests who shall be appointed by the Governor and shall hold office for four years and until his successor shall have been appointed and qualified, (Minn. Stat. Ann. 144.372) has the power and duty to administer and enforce all laws relating to the pollution of any waters of the State. (Minn. Stat. Ann. 144.373). Although the Water Pollution Control Commission has comprehensive power to enforce the water pollution control laws of the State, the State Board of Health is given the power and duty of administering all laws relating to the pollution of any waters of the State, so far as such pollution affects the public health. (Minn. Stat. Ann. 144.38).

The Secretary and Executive Officer of the State Board of Health serves as Secretary of the Commission (Minn. Stat. Ann. 144.372). Aside from the designation of hearing and investigating officials (Minn. Stat.

---

[1] Digests of State water pollution control laws prepared by Regional Attorneys, Federal Security Agency, Regions VII and IX, and the Office of General Counsel, Washington, D. C.

[2] Prepared by Division of Water Pollution Control, Public Health Service, Federal Security Agency, October 1950.

Ann. 144.373(10)) there is no statutory provision for delegation of authority by members of the Commission nor is an advisory council provided for by statute. But the State Board of Health has the statutory duty of furnishing the Commission with the employment of a qualified and experienced sanitary engineer to act as consultant to the Commission (Minn. Stat. Ann. 144.38(2)).

111. Powers and Duties

1. Development of Comprehensive Programs. The Water Pollution Control Commission is not given specific statutory direction to develop a comprehensive program. However, the Commission is given the power and duty to make such administrative classification of the waters of the State as it may deem advisable (Minn. Stat. Ann. 144.373(3)), and establish reasonable pollution standards of the waters of the State in relation to the public use to which they are or may be put (Minn. Stat. Ann. 144.373 (4)).

2. Issuance of Permits and Review of Plans and Specifications. The Commission has the power and duty: to require submission for its approval of plans for disposal systems or any part thereof and to inspect the construction for compliance with the approved plans (Minn. Stat. Ann. 144.373(7)); to issue, continue in effect, or deny permits for the discharge of sewage, industrial waste, or other wastes, or for the installation or operation of disposal systems or parts thereof (Minn. Stat. Ann. 144.373(7)); and to revoke or modify any permit whenever it is necessary, in the opinion of the Commission, to prevent or abate pollution of any waters of the State (Minn. Stat. Ann. 144.373(8)).

3. Enforcement. The Commission is authorized to issue orders after a hearing before itself or its authorized officer, member, or agent. Any person who will be directly affected by a final order of the Commission is required to be given written notice in person or by registered mail not less than ten days before the date of the hearing, specifying the time and place of the hearing. And such person has the right to be heard at the hearing and to submit evidence thereat (Minn. Stat. Ann. 144.375).

An appeal may be taken from an order of the Commission to the District Court of Ramsey County. The court of its own motion or on application of any party may, in its discretion, take additional evidence on any issue of fact or may try any or all such issues de novo, but no jury trial may be had (Minn. Stat. Ann. 144.375).

Pollution of any waters in violation of any order of the Commission constitutes a public nuisance and may be enjoined and abated as such (Minn. Stat. Ann. 144.377).

Violation of any provision of the State Water Pollution Control Act or of any regulation adopted by the Commission thereunder is a misdemeanor (Minn. Stat. Ann. 144.377(6)) punishable by imprisonment in the county jail for not more than three months, or by a fine of not more than $100 (Minn. Stat. Ann. 610.19).

The Commission, when it has determined that an emergency exists respecting any matter affecting the public health, may make a final order without notice and without a hearing.

But in addition to the Commission's enforcement powers, the State Board of Health has general charge of all springs, wells, ponds, and streams used as a source of water supply for domestic use and is under the duty to take all necessary and proper steps to preserve the same from such pollution as may endanger the public health. In case of violation the Board may with or without a hearing order any person to desist from causing such pollution and to comply with such direction of the Board as it may deem proper and expedient in the premises (Minn. Stat. Ann. 144.35).

4. Conduct of Studies, Investigations and Research. The State Water Pollution Control Commission is given the power and duty to investigate the extent, character, and effect of the pollution of the waters of the State and to gather data and information necessary or desirable in the administration or enforcement of pollution laws. (Minn. Stat. Ann. 144.373(3)). Further, the State Board of Health is given the duty of making such investigations of water pollution as may be required by the Water Pollution Control Commission (Minn. Stat. Ann. 144.38(2)).

5. Cooperation with other Public and Private Agencies. The Commission, so far as it is not inconsistent with its duties under the laws of the State, may assist and cooperate with any agency of another State or the United States, or of the Dominion of Canada or any province thereof, in any manner relating to water pollution control (Minn. Stat. Ann. 144.376(1)). The Commission may receive and accept money, property, or services from any person or from any agency or from any other source for any water pollution control purpose within the scope of its functions (Minn. Stat. Ann. 144.376(2)).

However, the State Board of Health is specifically authorized to cooperate with other departments of the State, other State offices, municipalities of all kinds, other States, the United States, the Dominion of Canada, or any province thereof, industries, societies, corporations, and individuals, to the end and purpose of protecting and freeing the waters of the State from pollution (Minn. Stat. Ann. 144.38(3)).

6. Administrative Powers. The Commission is given the power and duty to conduct investigations and hold such hearings as it may deem advisable and necessary for the discharge of its duties under the State Water Pollution Control Act; and to authorize any member, employee, or agent appointed by it to conduct such investigations or hold such hearings.

In any such hearing or investigation any member of the Commission or any employee or agent authorized by the Commission may administer oaths, examine witnesses, and issue in the name of the Commission subpoenas requiring the attendance and testimony of witnesses and the production of evidence relevant to any matter involved in any such hearing or investigation. Witnesses receive the same fees and mileage as in civil actions. In case of contumacy or refusal to obey a subpoena, the district court of the county where the proceeding is pending, or in which the person guilty of such contumacy or refusal to obey is found or resides, has jurisdiction upon application of the Commission or its authorized member, employee, or agent to issue to such person an order requiring him to appear and testify or produce evidence. Any failure to obey such order of the court may be punished as contempt by the court (Minn. Stat. Ann. 144.373(10)).

Any person operating a disposal system when requested by the Commission must furnish to it any relevant information. The Commission or any employee or agent thereof when authorized by it may examine any books, papers, records, or memoranda pertaining to the operation of the disposal system. Whenever it is necessary for the purposes of the State Water Pollution Control Act, the Commission or any member, employee, or agent thereof when authorized by it may enter upon any property, public or private, for the purpose of obtaining information or conducting surveys or investigations (Minn. Stat. Ann. 144.374).

A person must obtain a written permit for the construction, installation, and operation of any disposal system by submitting plans to the Commission for their approval (Minn. Stat. Ann. 144.377).

The Commission may prescribe and alter rules and regulations for the conduct of its operations and other matters within the scope of the powers under the State Water Pollution Control Act, provided that every rule or regulation affecting any other department or agency of the State or any person other than a member or employee of the Commission is filed with the Secretary of State (Minn. Stat. Ann. 144.373(9)).

The Commission may not issue a final order, except in case of emergencies, until due notice and hearing are given to the parties affected (Minn. Stat. Ann. 144.375).

The Commission is not required to hold hearings, unless it so desires, before issuing regulations or granting permits.

IV. Exemptions from Operation of Act

There are no geographical or functional exemptions from the operation of the State Water Pollution Control Act.

V. Presentation of Existing Rights and Remedies

The State Water Pollution Control Act may not be construed as repealing any provisions of law relating to the pollution of any waters of the State, but is required to be construed as supplementing the same and, in addition to the laws now in force, except as the same may be in direct conflict therewith (Minn. Stat. Ann. 144.378).

VI. Statement of Policy, Severability Clause, etc.

The State Water Pollution Control Act does not contain a statement of policy nor a severability clause.

VII. Interstate Agencies

Minnesota, together with South Dakota and North Dakota, comprise the Tri-State Waters Commission which is a corporate body which, among other things, was created for the purpose of studying problems concerning the pollution of water supplies in the interstate drainage basin area of the member States and recommending uniform legislation to the States involved for the control of such pollution. The Commission is authorized to review and approve plans for all waste disposal works on certain specified waters in the interstate drainage basin area (Approved by Congress April 2, 1938; 52 Stat. 150).

Representatives of Minnesota also have taken part in the Missouri River Basin Agreement with representatives of Colorado, Kansas, Missouri, Iowa, Montana, North Dakota, South Dakota, and Wyoming; the Great Lakes River Basin Agreement with representatives of Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York; the Upper Mississippi River Basin Drainage Agreement with representatives of Iowa, Wisconsin, Illinois, and Missouri. These are informal arrangements and do not constitute "interstate agencies" as defined in the Federal Act.

Montana

I. General Statement

The State Board of Health has "general oversight and care" of all water used as sources of water supply for domestic purposes; and of all waters "with respect to their condition and use as affecting the public health."

At its 1949 session, the legislature adopted the Council of State Governments' draft Water Pollution Control Enabling Act (Ch. 184, Laws 1949). Other statutes relating to water pollution control are collected in Ch. 13, Tit. 69, Rev. Codes, 1947. Statutes relating to the organization of the State Board of Health and its general powers and duties are collected in Ch. 1, Tit. 69, Rev. Codes, 1947, as amended by Ch. 57, Laws 1949. Apart from these laws, which are directed to the control of pollution in waters used for domestic purposes, criminal statutes make it unlawful to put dead animals, offal, etc. in all streams, ponds, lakes, or reservoirs (Sec. 94-3542, Rev. Codes, 1947); to deposit coal slack in any stream (Sec. 94-3551, Rev. Codes, 1947); and to poison any well, spring, or reservoir (Sec. 94-35-255, Rev. Codes, 1947).

The State Board of Health has been designated by the Surgeon General as the water pollution control agency for the State.

II. Administrative Organization

The State Board of Health consists of seven members (Sec. 69-102, Rev. Codes, 1947, as amended by Sec. 2, Ch. 57, Laws 1949).

The Board's jurisdiction in the area of water pollution control is Statewide.

There is an office of executive director within the Board, and the person holding that office is the administrative and executive head of the Board. Each division and section of the Board is responsible to the executive officer (Sec. 69-103, Rev. Codes, 1947, as amended by Sec. 3, Ch. 57, Laws 1949). Water Pollution control activities are centered in a division of sanitary engineering, apparently created by administrative action.

The executive officer appoints all subordinate personnel with the consent of the Board, subject to provisions of the merit system (Sec. 69-103, Rev. Codes, 1947, as amended by Sec. 3, Ch. 57, Laws 1949). There are no specific provisions for delegations of authority.

There is no advisory council.

III. Powers and Duties

1. Development of comprehensive program.

The Montana laws do not specifically provide for the development of a comprehensive program, nor for the setting of standards of water purity, nor for classifying waters. The Board of Health's authority, however, is broad. It is given "general oversight and care of all inland waters, streams, lakes, and ponds used as sources of water supply" (Sec. 69-1301, Rev. Codes, 1947); it may "cause examination of waters to be made to ascertain their purity and fitness for domestic use, or their liability to impair the interests of the public, or of persons lawfully using them, or to imperil the public health" (Sec. 69-1302, Rev. Codes, 1947); it may make rules and regulations to prevent pollution and "to secure the sanitary protection of all waters as are used for domestic purposes" (Sec. 69-1302, Rev. Codes, 1947); it shall make and publish in a monthly bulletin "rules and regulations for the collection of samples and analyses of water, either natural or treated" (Sec. 69-1304, Rev. Codes, 1947).

2. Issuance of permits and review of plans and specifications.

"Cities, towns, and all other corporations, companies, or persons shall submit to said Board, for its advice and approval, their proposed system of water supply, or of the disposal of drainage or sewage, and no city, town, or person or company shall proceed to build or install or enlarge or extend any system of water supply, drainage, or sewage disposal, without first obtaining the approval of the State Board of Health" (Sec. 69-1303, Rev. Codes, 1947; see also Sec. 69-125, Rev. Codes, 1947).

Municipal and private corporations and persons intending to construct any railroad, logging road, logging plant, electric plant, or manufacturing plant upon the watershed of any public water supply system must first furnish the State Board of Health with detailed plans and specifications of the sanitary precautions to be taken which must be approved by the Board (Sec. 69-1310, Rev. Codes, 1947).

Anyone drilling a water well intended for use by the public shall furnish the Board of Health with such information as the Board may by rule or regulation require (Sec. 69-1311, Rev. Codes, 1947).

3. Enforcement.

Upon a complaint the State Board may issue orders prohibiting the continuance of any pollution and requiring the removal of any cause of pollution (Sec. 69-1314, Rev. Codes, 1947). Presumably the Board may also issue orders on its own motion.

Administrative hearing is not required prior to issuance of the Board's orders. Miles City v. State Board of Health, 102 Pac. 69.

Persons aggrieved by any order of the Board may appeal to the district court (Sec. 69-1316, Rev. Codes, 1947). In the case of an appeal by a city or town, the statute is express that the case shall be tried de novo (Sec. 69-125, Rev. Codes, 1947).

Upon application of the State Board of Health or of any person interested, the district court of any county has jurisdiction in equity to enforce the Board's orders, rules and regulations (Sec. 69-1317, Rev. Codes, 1947). The Board has general authority to bring actions in the courts for the enforcement of the public health laws and the Attorney General is required to bring all suits and actions ordered by the Board (Secs. 4 and 6, Ch. 57, Laws 1949).

Violation of any provision of the act or of any rule, regulation or order of the State Board of Health is punishable by fine or imprisonment (Sec. 69-1320, Rev. Codes, 1947).

4. Conduct of studies, investigations, and research.

The Board of Health is authorized to establish and maintain an experiment station for the purpose of studying the best methods of preventing pollution, for the purification of water, and for the purification, disinfection, and disposal of sewage and domestic and manufacturing waste (Sec. 69-1318, Rev. Codes, 1947).

5. Cooperation with other public and private agencies.

Under the Council of State Government's draft enabling act passed by the last legislature, the State Board of Health has authority to take any action necessary to secure to the State the benefits of the Federal Water Pollution Control Act, to cooperate with other agencies and to enter into agreements with other States (Ch. 184, Laws 1949).

6. Administrative powers.

Under its general powers the State Board of Health has authority to hold hearings, administer oaths, subpoena witnesses, and to take testimony in all matters relating to the exercise and performance of its powers and duties (Sec. 4, Ch. 57, Laws 1949).

The Board has investigatory and visitorial powers (Secs. 69-1301, 69-1302, 69-1304, 69-1308, 69-1314, 69-1315, Rev. Codes, 1947).

No special procedures are provided in relation to the making of orders, granting of permits, the issuance of rules and regulations. Requirements respecting publication of orders, rules and regulations are contained in Sec. 69-1303, Rev. Codes, 1947.

IV. Exemption from Operation of Act

There are no exemptions specified.

V. Preservation of Existing Rights and Remedies

None.

VI. Statement of Policy, Severability Clause

No general statement of policy is set forth in the laws. The Enabling act contains a severability clause (Ch. 184, Laws 1949).

VII. Interstate Agencies

The State is not a member of an interstate agency.

North Dakota

I. General Statement

North Dakota has no comprehensive water pollution control legislation. The authority that exists is placed in the Water Conservation Commission, the State Department of Health, local boards of health under the supervision of the State Department, the Industrial Commission, and water conservation districts. Since no State agency has comprehensive authority in the water pollution control field, the Surgeon General has designated the State Department of Health as the State water pollution agency pursuant to the Federal Water Pollution Control Act.

North Dakota statutes relating to water pollution are found in R. C. 1943, 20-0124, 20-0612, 23-0109(4), 23-0307, 23-0405, 23-0407, 23-0502, 23-0512, 36-0705, 36-0714, 38-0804, 40-2204, c. 61-17, 61-0101, 61-0112, 61-0113, 61-0114, 61-0201, 61-0215, 61-0221, 61-0224, 61-0225, 61-0229, 61-0239; R. C. 1947 Supp., 21-0103, 23-0105, 23-0105(4), 23-0111, 40-0501(59), 40-2204, 61-0214, 61-0214f; and Laws 1937, c. 255, Laws 1939, c. 256, Laws 1949, c. 348.

II. Administrative Organization

1. Water Conservation Commission. The Commission, a public corporation, was established in 1937 (Laws 1937, c. 255) for water conservation, flood control, and the abatement of stream pollution. Its membership consists of the Governor, Commissioner of Agriculture and Labor, and five other members appointed by the Governor. The Commission may appoint assistants and fix their compensation. R. C. 1943, 61-0201 to 61-0213.

2. State Department of Health. The State Department of Health consists of the Health Council, the State Health Officer, the directors of divisions, and other employees of the Department.

The Health Council is composed of nine members appointed by the Governor. The members are representatives of various interested professions and groups and of the public.

The executive officer of the Department is the State Health Officer who is appointed by the Governor. He must be a physician who has special training or experience in public health administration.

The Department has certain named divisions, including a Division of Sanitary Engineering. Other divisions may be added by the Council. The State Health Officer appoints and prescribes the duties of the division directors. R. C., 1947 Supp., c. 2301.

III. Powers and Duties

1. Development of Comprehensive Programs. There is no express statutory authority to develop a comprehensive program, to set standards of water purity, or to classify waters.

2. Issuance of Permits and Review of Plans and Specifications. No sewage disposal plant may be constructed without the prior approval of the Commission and of the Department of Health. R. C., 1943, 61-0221.

3. Enforcement. There is no express authority to hold hearings or to issue orders. Every person who wilfully violates or refuses or omits to comply with any lawful order, direction, prohibition, or regulation of a board of health or of a health officer is guilty of a misdemeanor and shall be punished by imprisonment for not more than 30 days or by a fine of not more than $1,000, or both. R. C., 1943, 23-0512.

Every person who throws or deposits any gas tar or refuse of any gas house or factory into any public water or into any sewer or stream emptying into public water is guilty of a misdemeanor, R. C., 1943, 61-0112.

The following acts are also misdemeanors punishable by a fine of not more than $100.

(1) The placing of dead animals, refuse, privies or privy vaults upon the banks or in the water of any lake or stream within the jurisdiction of the State;

(2) The placing of any structure or corral within which horses, cattle, swine, or sheep are kept within 60 feet of the top of the bank of a stream or lake;

(3) The placing of a slaughterhouse or grave within 80 feet of a lake or stream. R. C., 1943, 61-0113 and 61-0114.

Any person who places sawdust or other refuse in water in which fish abound, or in which the State or Federal Government has placed or may place fish or fish eggs, is guilty of a misdemeanor and shall be punished by a fine of not more than $100 or by imprisonment of not more than 30 days, or both. R. C., 1943, 20-0124 and 20-0612.

To deposit liquid waste from a rendering plant upon the surface of the ground, or to dispose of it in a manner which makes any water supply unfit for human or livestock use is a misdemeanor punishable by a fine of not more than $100 or by imprisonment of not more than 90 days, or both. R. C. 1943. 36-0705 and 36-0714.

4. Conduct of Studies, Investigations, and Research. The Water Conservation Commission has power to investigate and plan all works, dams, and projects "to provide sufficient water flow for the abatement of stream pollution." R. C. 1947 Supp., 61-0214f.

The Commission may investigate, plan, and cooperate with other States, the Federal Government, and the Dominion of Canada for the purpose of preventing water pollution. R. C. 1943, 61-0224.

The duties of the State Health Officer include the duty to "study health problems and plan for their solution as may be necessary." R. C. 1947 Supp., 23-0105(4). The Director of the Division of Public Health laboratories of the Department shall, among other things "Cause sanitary statistics to be collected and tabulated, and cause to be ascertained by research work such methods as will lead to the improvement of the sanitation of the various parts of the State." R. C. 1943, 23-0109(4).

5. Cooperation with Other Public and Private Agencies. The Water Conservation Commission is authorized to investigate, plan, cooperate, and make all contracts or compacts with the United States, Canada, or any State for the purpose of preventing water pollution. The Commission may also accept and use any funds from the United States for such purpose. R. C. 1943, 61-0224.

Any State officer, department, or board which is authorized to deal with the United States or any State concerning water pollution must, before any action is taken, obtain the approval of the Commission. R. C. 1943, 61-0225.

For the purpose of obtaining financial aid from the United States, the Commission may adjust the plans and operation of any project to conform to the laws and regulations of the Federal Government. R. C. 1943, 61-0239.

The Department of Health is authorized to accept Federal funds for "public health work." R. C. 1947 Supp., 23-0111.

Municipalities are authorized "to accept aid from, cooperate and contract with, and to comply with and meet the requirements of any Federal or State agency for the establishment, construction and maintenance of public works . . . for the prevention of stream pollution or for sewage disposal . . ." R. C. 1947 Supp., 40-0501(59).

6. Administrative Powers. The statutes provide that all water within the State belong to the public. R. C. 1943, 61-0101. R. C. 1943, 61-0229, provides that the Water Conservation Commission "shall have full control over all unappropriated public waters of the State, whether above or under the ground, to the extent necessary to fulfill the purposes of this chapter." R. C. 1947 Supp., 61-0214, provides that the Commission "shall have full and complete power, authority, and general jurisdiction: . . ."

> "1. To investigate, plan, regulate, undertake, construct, establish, maintain, control, and supervise all works, dams, and projects, public and private, which in its judgment may be necessary or advisable:
>
> . . . .
>
> f. To provide sufficient water flow for the abatement of stream pollution;
>
> "2. To define, declare, and establish rules and regulations:
>
> . . . .
>
> c. For the complete supervision and control of acts tending to pollute watercourses, for the protection of the health and safety of all the people of the State;
>
> "3. To exercise full power and control of the construction, operation, and maintenance of works and the collection of rates, charges, and revenues realized therefrom;
>
> . . . .
>
> "5. To exercise all express and implied rights, power and authority, that may be necessary, and to do, perform, and carry out all of the expressed purposes of this chapter and all of the purposes reasonably implied incidentally thereto or lawfully connected therewith."

The powers granted the Commission do not limit or deprive the Department of Health of its jurisdiction to prevent water pollution. The Commission may not declare water polluted without a finding to that effect by the Department. R. C. 1943, 61-0215.

Although, as indicated above, the statutes do not expressly authorize the Commission to hold hearings or to order persons to cease polluting water, such authority would seem to be reasonably implied from the foregoing statutory provisions.

Statutes enacted prior to 1895 authorized municipalities to empty untreated sewage into streams. R. C. 1943, 40-2204. See also R. C. 1943, 20-0612 (enacted in 1909) and 61-0114 (enacted prior to 1895), which recognize this authority. Although these statutes have never been expressly repealed, it may be that the later statutes which established the Commission and granted it water pollution control powers modified them by implication.

R. C. 1947, Supp., 23-0103, provides that the Health Council shall: "Establish standards, rules, and regulations which are found necessary for the maintenance of public health, including sanitation and disease control."

R. C. 1947 Supp., 23-0104 provides: "All rules and regulations promulgated by the health council under the powers granted by any provisions of this Act (title) shall be binding upon all county and municipal health officers, . . . and shall have the force and effect of law."

The State Health Officer is required to enforce all rules and regulations of the Council and to hold local boards of health responsible for the enforcement of State regulations. R. C. 1947 Supp., 23-0105.

The county superintendents of public health are required, under the supervisory control of the Department of Health, to investigate public water and ice supplies which are suspected of being infected and to cause them to be condemned when necessary. R. C. 1943, 23-0307.

The county boards of health are authorized, under the supervisory control of the Department of Health, to supervise public water supplies and sewerage systems outside the corporate limits of any city. R. C. 1943, 23-0502.

City health officers are required to enforce the rules and regulations of the State Department of Health and of the city boards of health, the health ordinances of the cities and the health laws of the State. R. C. 1943, 23-0405 and 23-0407.

Water conservation and flood control districts may be organized on the approval of the Water Conservation Commission. The Board of Commissioners of such a district is authorized to make rules and regulations to prevent the pollution of water within the district. Laws 1949, c. 348, sec. 8.

The Industrial Commission is authorized to make rules and regulations which require oil and gas wells to be drilled, cased and plugged in such a manner that pollution of fresh water supplies will be prevented. The regulations may also require that a report of the plugging be made to the State Geologist within 60 days after completion of a well. R. C. 1943, 38-0804.

IV. Exemptions from Operation of Act

The only exemption from the water pollution control statutes is found in R. C. 1943, 20-0612, 40-2204, and 61-0114, supra, which may authorize municipalities to empty untreated sewage into streams.

V. Preservation of Existing Rights and Remedies

Laws 1937, c. 255, which created the Water Conservation Commission and granted it water pollution control powers provided in section 20 that nothing contained in the act should "repeal, amend, or modify any existing Acts or statutes pertaining to the appropriation or use of water except as herein otherwise provided . . ." A similar provision was contained in the re-enactment of 1939. Laws of 1939, c. 256, section 20.

As indicated above, R. C. 1943, 61-0215, provides that nothing in the act deprives the Department of Health of its jurisdiction to prevent water pollution.

VI. Statement of Policy

R. C. 1943, 61-0201, provides that the general welfare and health of all the people require that the regulation and prevention of water pollution necessitates the exercise of the sovereign powers of the State and that such regulation and prevention are affected with a public purpose; that the Water Conservation Commission in the exercise of its powers and in the performance of its duties shall be considered to be performing a governmental function for the benefit, welfare, and prosperity of all the people of the State.

Laws of 1937, c. 255, and Laws of 1939, c. 256, stated in sections 33 and 34 respectively that the provisions of the acts were severable and that if any one was unconstitutional, void, or inoperative, the others should remain in full force and effect.

VII. Interstate Agencies

North Dakota participates in the following interstate agencies:

(1) The Missouri Basin Health Council, which includes the States within the area of the Missouri Drainage Basin Office. The other States are Nebraska, Montana, South Dakota, Wyoming, Minnesota, Colorado, Kansas, and Missouri.

(2) Tri-State Waters Commission. The Commission's duties and powers include the abatement of pollution of the Red River. Minnesota and South Dakota are the other participants. R. C. 1943, c. 61-17; S.D.C., 55.4901 to 55.4905; M.S.A., 114.09 to 114.11; approved by Congress April 2, 1938, 52 Stat. 150. Although the life of the Commission has never been officially terminated, it has not functioned for several years.

(3) Inter-State Sanitary Committee. This is an informal agreement between the North Dakota, South Dakota, and Minnesota Health Departments. The Committee has materially contributed to pollution abatement of the Red River.

South Dakota

I. General Statement

Subject to vested rights and except as otherwise provided all waters within the State belong to the public. Pollution of streams by those over whose lands they pass is forbidden. SDC, 61.0101.

In 1935 the South Dakota legislature created a committee on water pollution. The committee is charged with classifying waters and preventing pollution of "Class A" waters.

The Department of Health also has certain duties and powers pertaining to sewage disposal and the prevention of water pollution.

Since the committee has comprehensive powers to prevent water pollution, the Surgeon General has designated it as the State water pollution agency pursuant to the Federal Water Pollution Control Act.

II. Administrative Organization

1. The committee on water pollution consists of the State Health Officer, who is ex officio chairman, the State Engineer, and the Director of Game and Fish. The Director of the Division of Sanitary Engineering of the Department of Health is the secretary and executive officer of the committee. SDC, 61.0106. The technical work, unless otherwise provided, is placed under the direction of the Director of the Division. SDC, 61-0108.

2. The Department of Health consists of the Public Health Advisory Council, the State Health Officer, directors of divisions, and other employees necessary to operate the Department.

The Council consists of nine members appointed by the Governor. They receive $10. a day while actually engaged in the discharge of their duties.

The State Health Officer is appointed by the Governor with the approval of the Council. He is required to be a graduate of a recognized medical school and to have had special training in public health administration. He must be licenses to practice medicine in South Dakota. He is the administrative officer of the Department and acts as secretary to the Council. Divisions are established and personnel appointed by him. Laws 1949, ch. 105.

III. Powers and Duties

1. Development of Comprehensive Programs. Neither the Department nor the committee has specific statutory authority to develop comprehensive programs.

The committee shall classify the public waters of the State into "Class A" waters and "Class B" waters. "Class A" waters are those in which pollution can be so controlled that they shall not be unwholesome and unfit for domestic use or unsafe as a source of public water supply or deleterious to plant or fish life, or shall not cause a public nuisance. "Class B" waters are those which are more important to the welfare of the people as carriers of wastes, provided such **wastes** are not detrimental to the public health.

In passing on permits to create new pollution (see 2, infra) of "Class A" waters, the water pollution committee shall prescribe the standards of water quality and purity of sewage and industrial or other wastes necessary to maintain the receiving waters as "Class A." SDC, 61.0109, as amended by Laws 1947, ch. 416.

2. Issuance of Permits and Review of Plans and Specifications. No one shall cause new pollution in the form of sewage, industrial wastes or otherwise, of "Class A" waters without applying for and receiving a permit from the water pollution committee. SDC, 61-0109, as amended Laws 1947, ch. 416.

3. Enforcement. If investigation, at the direction of the committee, by the Director of the Division of Sanitary Engineering reveals unlawful pollution, the committee shall make an order requiring the alleged polluter to show cause why he should not be required to cease such pollution. After a hearing on the order to show cause, the committee may, if the evidence so justifies, further order the polluter, within a specified time, to refrain from the acts which cause the pollution.

The committee is required to keep a complete record of the proceedings before it. Its orders may be enforced by or appealed to the circuit court of the county where the pollution occurs. The appeal is on the record and is to the court without a jury except in cases where the right to trial by jury is preserved by the Constitution or by a statute. SDC, 61.0110 to 61.0116 and ch. 33.42.

The Public Health Advisory Council has the power:

> "4. To make, alter, and enforce, after approval of the Attorney General, orders, directions, or regulations as may be necessary to preserve and protect the public health and to regulate by requiring the taking out of licenses or other appropriate means, control, and, in proper cases, prohibit and suppress any of the following matters:
>
> . . . .

> (b) The disposal of sewage:
>
> . . . .
>
> "(e) The pollution of streams and other waters:
>
> . . . .
>
> "The failure to obey the process, subpoena, order, rule, regulation, judgment or other legal command of the Council, or the violation of any rule, regulation, order or legal command of the Council may be enforced by proper legal proceedings in a court of competent jurisdiction."

Laws 1949, ch. 105, sec. 5 and 8.

The council is required to keep a correct record of its proceedings. Any action by it is appealable to the circuit court. Upon approval of an appeal bond in the sum of $500. the order appealed from shall be stayed pending final determination of the controversy. The statute seems to contemplate an appeal on the record. Laws 1949, ch. 105, sec. 7, SDC, 27.0114.

There is no specific statutory authority for emergency summary action by either the Department or the committee.

Any person who violates the rules and regulations of the Department of Health is guilty of a misdemeanor. SDC, 27.9934.

Any person who places a dead animal or refuse in any river, stream, or lake, or in such proximity to such water as to cause pollution, is guilty of a misdemeanor. SDC, 13.1506 and 61.9901.

Any person who willfully and unlawfully commits any action which grossly endangers the public health is guilty of a misdemeanor. SDC, 13.1501.

4. Conduct of Studies, Investigations, and Research. It is the duty of the committee on water pollution to instruct the Director of the Division of Sanitary Engineering of the Department of Health to carry on such investigations as may be necessary. The committee may also on its own initiative or upon a petition of a municipality or board of health, or of 100 electors, cause the Director of the Division to investigate pollution of "Class A" waters. SDC, 61.0108, 61.0110, and 61.0111.

The Public Health Advisory Council has the power to make or cause to be made such investigations as may be required in the interest of public health. Laws 1949, ch. 105, sec. 5.

5. Cooperation with Other Public and Private Agencies. The statutes are silent with respect to cooperation with other public and private agencies, or with the United States or other States, and with respect to authority to participate in the benefits of the Federal Water Pollution Control Act.

6. Laws 1949, ch. 105, sec. 8 authorizes the Advisory Council to make such rules and regulations as are necessary for the proper administration of that chapter.

IV. Exemptions from Operation of Act.

"Class B" waters are exempt from the authority of the committee on water pollution.

V. Preservation of Existing Rights and Remedies.

No specific statutory provisions.

VI. Statement of Policy.

None.

VII. Interstate Agencies.

South Dakota participates in the following interstate agencies:

(1) The Missouri Basin Health Council, which includes the States within the area of the Missouri Drainage Basin Office. The other States are Iowa, Nebraska, Montana, North Dakota, Wyoming, Minnesota, Colorado, Kansas, and Missouri.

(2) Tri-State Waters Commission. The Commission's duties and powers include the abatement of pollution of the Red River. Minnesota and North Dakota are the other participants. SDC, 55.4901 to 55.4905; R.C. (ND) 1943, c. 61-17; M.S.A., 114.09 to 114.11; approved by Congress April 2, 1938, 52 Stat. 150. Although the life of the Commission has never been officially terminated, it has not functioned for several years.

(3) Inter-State Sanitary Committee. This is an informal agreement between the North Dakota, South Dakota, and Minnesota Health Departments. The Committee has materially contributed to pollution abatement of the Red River.

(4) The Public Health Service and the health departments of South Dakota, Iowa, Missouri, Kansas, and Nebraska have entered into a written agreement effective January 1, 1950, to make a survey of pollution of the Missouri River from Yankton, South Dakota, to the mouth.

Wyoming*

1. General Statement

The Department of Public Health has "general oversight and care" of all waters used as sources of supply for domestic purposes and of all waters "with respect to their condition and use as affecting the public health"**(Sec. 63-201). The State Board of Health, within the Department of Public Health, has been designated by the Surgeon General as the water pollution control agency for Wyoming.

General statutes relating to water pollution and control are contained in Articles 1 and 2, Chapter 63, of the Wyoming Compiled Statutes, as amended. Aside from these provisions the criminal statutes make it unlawful for the owner of any sawmill, reduction works, smelter, or other manufacturing or industrial works, or any other person, to deposit in any waters wherein are living fish any sawdust, chemicals, milltailings, or any other refuse or deleterious substance that might tend to destroy the fish or pollute or render the waters unfit for domestic, irrigation, stock, or any other purpose (Sec. 47-507). Section 9-220 makes it unlawful to poison any spring, well, or reservoir of water with intent to injure or kill a human being.

II. Administrative Organization

The Department of Public Health consists of two divisions: The State Board of Health and the Division of Administration (Sec. 63-144). Specific and direct authority over water pollution control rests in the Division of Administration (Sec. 63-149). The Board of Health acts in an advisory capacity to the State Director, who is the administrative and executive head of the Division of Administration (Sec. 63-147(1)). The Board also has authority to determine general policies to be followed by the Division of Administration in administering public health laws (Sec. 63-147(2)).

The Department of Public Health's jurisdiction in the area of water pollution control is Statewide.

Water pollution control activities of the Department of Public Health are centered in a Division of Public Health

---

*Statutory references are to Wyoming Compiled Statutes, 1945, as amended, Cum. Supp. 1949.

**Senate Bill No. 30, enacted by Wyoming Legislature February 9, 1951, provides that any pollution which adversely affects livestock, agricultural crops, wildlife, fish or aquatic life, is also deemed to affect public health.

Engineering and Sanitation apparently established by administrative action. Employees are appointed subject to merit system provisions (Sec. 63-146). The power to provide for delegations of authority to subordinate officials is implied in section 63-149.

A council appointed by the Governor, consisting of the Director of the State Department of Public Health, State Game and Fish Commissioner, State Engineer, State Commissioner of Agriculture, and five other members, one a representative of industry and one a representative of municipal government, is charged with the primary duty of advising the State Department of Public Health in developing a comprehensive program for the prevention, control, and abatement of new or existing pollution of the waters of the State (Section 63-201).

III. Powers and Duties

1. Development of comprehensive program.

The Wyoming laws do not specifically provide for the setting of standards of water purity, nor for classifying waters. Amendments in 1947 provide for the enforcement of such sanitary standards as to quality of water and as to quality of the effluent of sewage treatment plants "as are or may be established by law" (Sec. 63-149). No such standards appear to have been established "by law." However, the Department of Public Health does have broad authority in this field. It is given "general oversight and care of all inland waters and of all streams, lakes, and ponds used" as sources of water supply (Sec. 63-201); it may "cause examination of waters to be made to ascertain their purity and fitness for domestic use or their liability to impair the health of the public or of persons lawfully using them" (Sec. 63-202, also 63-112); it may "make rules and regulations to prevent pollution and to secure the sanitary protection" of waters (Sec. 63-202); it has power to abate nuisances when necessary for the protection of the public health (Sec. 63-149); it exercises sanitary control over the use of water employed in the irrigation of vegetables (Sec. 63-149).

2. Issuance of permits and review of plans and specifications.

"Cities, towns and all other corporations or persons shall submit to . . . /the Department of Public Health/ for its advice and approval their proposed system of water supply or of the disposal of drainage or sewage, and no city, town or persons or company shall proceed to build or install or enlarge or extend any system of water supply, drainage or sewage disposal without first obtaining the approval of the . . . /Department of Public Health/" (Sec. 63-204).

"No sewage, drainage, refuse or polluting matter . . . shall be discharged into any such stream, spring, lake, pond

. . . unless such sewage, drainage, refuse or polluting water shall have been purified, so as to render it harmless in such a manner and under such conditions and restrictions as the . . . /Department of Public Health/ may direct; provided that no city or town shall be prohibited or enjoined from discharging its sewage into a river or body of water unless such sewage so pollutes the water as to be dangerous or injurious to the public health" (Sec. 63-205).

Municipal and private corporations and persons intending to construct any railroad, logging road, logging plant, electric plant, or manufacturing plant upon the watershed of any public water supply system must first furnish the Department of Public Health with detailed plans and specifications of the sanitary precautions to be taken which must be approved by the Department (Sec. 63-206).

3. Enforcement.

Upon complaint the Department of Public Health may issue orders prohibiting the continuance of any pollution and requiring the removal of any cause of pollution (Sec. 63-207). Presumably the Department of Public Health may also issue orders on its own motion.

There are no statutory provisions for administrative hearings prior to issuance of the Department's orders.

Persons aggrieved by any order of the Department may appeal to the district court (Sec. 63-209). The statutes are silent as to whether such appeals shall be tried de novo.

Upon application of the State Department or of any person interested, the district court has jurisdiction in equity to enforce the Department's orders, rules and regulations (Sec. 63-210).

Violation of any provision of the Act or of any rule, regulation, or order of the State Department of Public Health is punishable by fine or imprisonment (Sec. 63-212).

4. Conduct of studies, investigations, and research.

The Department of Public Health has authority to make studies and investigations relating to water pollution (Secs. 63-149, 63-202, 63-211).

5. Cooperation with other public and private agencies.

There are no provisions relating specifically to action to secure to the State benefits of the Federal water pollution control act. However, section 63-148 contains a general authorization to accept and administer Federal aid moneys allotted for public health work.

The statutes are silent with respect to agreements with agencies of other States.

6. Administrative powers.

There is general authority in the Department of Public Health to hold hearings, administer oaths, subpoena witnesses, and to take testimony in all matters relating to the exercise and performance of its powers and duties (Secs. 63-147, 63-149).

The Department has investigatory and visitorial powers (Secs. 63-149, 63-112, 63-208).

Procedures are not spelled out with relation to the making of orders, granting of permits, the issuance of rules and regulations. Requirements respecting the publication of orders, rules and regulations are contained in section 63-203.

IV. Exemptions from Operation of Act

There are no exemptions specified.

V. Preservation of Existing Rights and Remedies

None.

VI. Statement of Policy, Severability Clause

None.

VII. Interstate Agencies

The State is not a member of an interstate agency.

POLLUTION PREVENTION MEASURES REQUIRED

Present water uses and increased or additional uses possible with improved water quality together with protection of water rights and property values largely determine pollution prevention measures needed. The objective of water pollution control programs is to preserve and reclaim water to best serve these interests. Treatment requirements like other aspects of water resources development are generally influenced by economic considerations. In addition, the intangible aspects of moral obligation, aesthetic values and nuisance conditions exert a powerful and positive influence on the justification of waste treatment facilities.

Quality objectives have been fairly well developed for such waters used for domestic and industrial supply, recreation, bathing, and support of fish and other aquatic life. Objectives are less well defined for other uses.

Among the more important objectives of a water pollution control program is protection of water quality in streams used as sources of public water supplies. The quality of raw water is an important factor in the design of water treatment facilities and in their operation and maintenance. The factor of safety which can be incorporated in the best water treatment facilities varies, however, inversely with the concentration of bacteria and toxic elements in the source of supply. Therefore, public health and waterworks officials generally measure water quality in terms of its bacteriological, physical, and chemical characteristics. While definite standards of raw water quality generally have not been adopted, the Manual of Recommended Water Sanitation Practice, Public Health Service Bulletin No. 296, 1946, recommends the following criteria: Underground waters not subject to any possible contamination and meeting in all respects the requirements of the Public Health Service Drinking Water Standards, as shown by satisfactory, regular and frequent sanitary inspections and laboratory tests, require no treatment. Underground or surface waters which are subject to a low degree of contamination, coliform numbers averaging not more than 50 M.P.N. per 100 ml. in any month and meeting the requirements of the Public Health Service Drinking Water Standards in all other respects, should receive a minimum of simple chlorination or its equivalent. Waters which require filtration for turbidity and color removal, waters of high or variable chlorine demand, and waters polluted by sewage to such an extent as to be inadmissible in the prior groups but containing numbers of coliform bacteria averaging not more than 5,000 M.P.N. per 100 ml. in any one month and exceeding this number in not more than 20 percent of the samples examined in any one month should be provided complete rapid sand filtration treatment or its equivalent, together with continuous postchlorination. Waters which meet the requirements of the previous statement with respect to limiting monthly average coliform numbers but showing numbers of coliform exceeding 5,000 M.P.N. per 100 ml. in more than 20 percent of the samples examined during any one month and not exceeding 20,000 per 100 ml. in more than 5 percent of the samples examined during any month should be provided auxiliary treatment in addition to complete filtration and postchlorination. Auxiliary treatment as used here is presedimentation or prechlorination or their equivalents, either separately or combined as may be necessary. Long time storage for periods of 30 days or more represents a permanent and reliable safeguard which in many cases would provide something more than an effective substitute for one or both of the two other methods indicated. Waters which do not meet the requirements cited are considered unsuitable for use as sources of water supply unless they can be brought into conformance with the requirements by means of prolonged preliminary storage or some other measure of equal permanence and reliability as heavy prechlorination and preliminary coagulation and sedimentation.

In addition to recommended bacterial requirements, waters for public supply should not contain toxic, taste producing, or otherwise harmful substances, or organisms not readily and completely removed by water treatment processes. Also, water should be free of excessive amounts of acid, microscopic organisms, and organic matter causing any interference with the normal operation and efficiency of water treatment processes. Whether or not upstream domestic and industrial waste is treated thus often determines the acceptability of a water for domestic or industrial supply.

Standards adopted by the Public Health Service for Drinking and Culinary Water Supplied by Common Carriers in Inter-State Commerce prescribe limiting maximum concentrations of certain chemical substances inimical to public health, including the following:

Substance	Maximum concentration
Lead	0.1 ppm.
Fluoride	1.5 ppm.
Arsenic	0.05 ppm.
Selenium	0.05 ppm.
Hexavalent chromium	0.05 ppm.

These standards have received official approval by the American Water Works Association and general acceptance by official health agencies and water works authorities and are widely used as one of the guides for evaluating water quality in administrating a water pollution control program.

Also of importance are those substances which cause problems of taste and odors. Of particular concern are phenols and related compounds, which, in minute concentrations, cause repugnant tastes and odors in water supplies. Pollution control programs aim for the practical elimination of these substances from waters serving as a source of domestic supply.

Quality requirements for industrial water supply vary widely, depending upon the needs of the industry under consideration. Of general concern are the organic and biological constituents, toxic substances, and properties of corrosion, encrustation, and slime formation of the available waters. Waste control measures contribute materially to improvement of these qualities.

It is generally agreed that a minimum of 5.0 parts per million of dissolved oxygen is necessary in streams of the area that otherwise afford a suitable fishery habitat for support of balanced aquatic life. Because of limited dilution water available during critical periods of low flow in other than the Missouri River, secondary treatment, or removal of not less than 75 percent of the Biochemical Oxygen Demand, is required for most sources of pollution to protect downstream water uses. Where the quantity of waste is large, as in principal towns where industry is concentrated, a degree of B.O.D. removal substantially in excess of 75 percent may be required to maintain desirable oxygen levels. Removal of B.O.D. approaching 90 percent is possible with properly designed and well operated secondary treatment facilities.

Contamination of bathing waters by sewage, especially that of recent origin, is objectionable. Also, water for recreational usage should be free from floating solids, sludge banks, odors, and discoloration. Quality objectives for the bacteriological quality of bathing waters are not firm. However, those recommended by the Joint Committee* on Bathing Places, together with sanitary surveys, are widely employed in administration of pollution control programs as related to bathing waters. Under Joint Committee classification, Class A waters are those of high quality containing less than 100 coliform organisms per 100 ml. of water. Class B waters are those of fair quality containing between 100 and 500 coliform organisms per 100 ml. Class C are waters of poor quality containing between 500 and 1,000 coliform organisms per 100 ml. Class D waters, very poor in quality, are those containing an excess of 1,000 coliform organisms per 100 ml. Other indices of quality, as fecal streptococci, are receiving increasing attention, however sanitary surveys must continue to play the major role in pollution control programs as related to bathing waters.

The following is suggested for bacteriological quality of irrigation water: (1) Sewage used for irrigation of forage crops should be given treatment insuring a consistent reduction in coliform bacteria of not less than 90 percent; and (2) sewage used for irrigation of human food crops should be given treatment insuring a consistent reduction (a) in suspended solids of not less than 75 percent, (b) in 5 day 20° C., B.O.D. of not less than 75 percent, and (c) in coliform bacteria of not less than 98 percent, unless discharged into a stream where the volume of dilution water, available during the low flow periods in which irrigation diversions may occur, is at least 10 times greater than the anticipated maximum daily volume of sewage, in which case a bacterial reduction of 90 percent may be acceptable. Where the time of passage from plant discharge to irrigation diversion is such as to permit the normal death rate of bacteria as evidenced by the die-away curve to provide equivalent bacterial reduction, the requirement of (1) and (2) above may be appropriately modified.

---

*Joint study by American Public Health Association and Conference of State Sanitary Engineers, "Recommended Practice for Design, Equipment and Operation of Swimming Pools and Other Public Bathing Places" 1949.

The protection of water rights must also be considered in determining pollution prevention measures needed. Comprehensive State water pollution control measures will not interfere with water rights under the three prevailing American legal doctrines of water law - the common law doctrine, reasonable use doctrine and prior appropriation doctrine - none of which gives a license to pollute waters. The common law or riparian rights doctrine widely applied in States east of the 98th meridian holds that, "all persons owning land abutting on a natural stream have a right to demand that the water shall pass their land undefiled in quality and undiminished in quantity."[1] Interpretations of the doctrine of reasonable use vary but, in general, it is applied to stream uses that do not substantially lessen quantity or impair quality of the water. West of the 98th meridian the prior appropriation doctrine is usually accepted, although in many areas State water laws incorporate a portion of both the reasonable use and prior appropriation doctrines. Where the doctrine is appropriated water rights prevail, consumptive use of water is permitted but no license is thus given to return water to the stream in a defiled condition. The water laws of the States of North Dakota and South Dakota contain applicable portions of both doctrines. The reasonable use doctrine governs in the State of Minnesota while the doctrine of prior appropriation has been established in Montana and Wyoming.

Waste treatment measures are usually tailored to specific needs following an engineering evaluation of local sanitary problems. Municipal sewage treatment plants are primarily of two general types, one of which removes settleable material from liquid waste under quiescent flow conditions and the other removes nonsettleable and dissolved polluting material by biological means. Within these categories numerous combinations or adaptions thereof can be used to meet variant characteristics of wastes from a community and treatment requirements indicated by water uses of the receiving stream. Industrial waste treatment processes vary widely, often within the same general type of industry. Changes in manufacturing processes and in by-products recovery, salvage, and improved housekeeping practices may often prove very effective measures for reducing and thus controlling industrial waste pollution.

Control of industrial waste pollution may present an entirely different problem from that incurred in controlling municipal waste pollution since industrial wastes may contain toxic or otherwise objectionable substances not amenable to either sedimentation or biological treatment. However, the objective of the control program remains the same--protection of waters by reduction of objectionable substances to within tolerance levels compatible with water uses. The water pollution control programs in this area are based on these premises.

While sewage and waste treatment processes cannot be controlled precisely, they can be regulated between rather well established limits. The effective removal of solids from domestic wastes by sedimentation is termed primary treatment and is generally considered to reduce B.O.D.* from 25 to 40 percent. The reduction of Biochemical Oxygen Demand by biological methods is termed secondary treatment. A plant incorporating effective primary and secondary treatment is generally considered capable

[1] Merriman and Wiggins, American Civil Engineers Handbook, page 1750--Legal and Economic Features of Water Rights, 5th Edition.

*Biochemical Oxygen Demand is the quantity of oxygen utilized by microorganisms under aerobic conditions while feeding on and stabilizing organic materials.

of removing from 75 to 85 percent of the organic polluting material and may be capable of effecting 90 percent removal. Greater reduction, sometimes referred to as tertiary treatment, can be obtained by repetitive passages of wastes through the treatment processes or by increasing the number of combinations of treatment processes. All of these sewage and industrial waste treatment methods are effective in removing only the organic materials that can be removed by sedimentation or those that can be stabilized by biological action. Inorganic waste such as most acids, alkalies, salts, and the metallic ions must be controlled by recovery, neutralization, storage, evaporation or other specialized processes. An excellent example of an effective method of controlling inorganic industrial waste is the return to appropriate underground formations of waters of high salt content which were originally pumped with oil to the earth's surface. In general, the water pollution control agencies have endorsed the following treatment concepts:

(1) Toxic substances including metallic ions, phenol compounds, oils, and acids must be virtually excluded from streams. Such substances are inimical to aquatic life and if present in sufficient concentrations are hazardous to human life and to livestock.

(2) Effective removal of settleable and floating solids is the minimum degree of treatment required to prevent sludge banks, floating materials and nuisance conditions in the receiving streams. Property values, recreation, fishing, stock watering, and other water uses are thus provided a measure of protection.

(3) The degree of treatment required beyond effective primary treatment (2 above) is influenced by downstream water uses and by the amount of dilution water available during periods of low flow and ice cover. Biological removal of dissolved organic materials and bacteria must be provided where water uses make it necessary to: (a) maintain dissolved oxygen at levels necessary for balanced aquatic life; (b) maintain desirable water quality for domestic, industrial or recreational uses; and (c) prevent nuisance or health hazards.

(4) For industrial wastes similar in nature to municipal wastes, treatment requirements are the same as those for municipal wastes. For industrial wastes not similar to municipal wastes, treatment requirements are such as will prevent substantial deterioration of water quality in the receiving stream.

Future water pollution control programs in the area will be largely a matter of extending present work with emphasis on:

(1) Enactment of comprehensive pollution control legislation where needed.

(2) Provision of plants where none now exist, and improvement of inadequate existing plants.

(3) Dissemination of information concerning effects of pollution on public health, fishing, and other water uses.

(4) Improving operation and maintenance of existing sewage works.

(5) Surveillance of stream conditions to supplement sewage treatment plant inspections so that needs for additional or improved waste treatment can be foreseen well in advance of actual necessity, thus enabling planning and construction to be carried forward with a minimum of delay.

Surveys of most of the sources of pollution in this region have been made by the State water pollution control agencies and reports, containing findings of the investigations together with recommendations for correcting or improving conditions, have been provided municipal and industrial officials and other interested parties. These reports serve to indicate corrective measures needed. The State water pollution control agencies have further cooperated with representatives of numerous industries and municipalities through conferences on specific problems of pollution, and have worked closely with engineers employed by municipalities and industries to study pollution problems. These activities were inaugurated in the past as part of a continuing program. Where engineering studies have been made they substantiate treatment needs as indicated in this report.

The ultimate step in the control of stream pollution is the construction and proper operation of sewage and industrial waste treatment facilities. Such action requires knowledge of sources of pollution and amounts of wastes discharged. This report delineates these sources and amounts of wastes and pollution abatement needs are depicted in figure 6. Subsequently these facts must be brought to the attention of public officials, industry, and the public at large so that they may act intelligently upon their local pollution problems. A sound body of law should be available in the States to support pollution control agencies in their activities.

Adequate stream flow as related to the degree of waste treatment provided is vital to the proper assimilation of wastes discharged to watercourses. A detailed discussion of this matter is presented elsewhere in this report and recommendations for desirable minimum flows at various specific locations are given in the Sub-Basin sections of the report. Water resources development programs should include public health considerations. Minimum stream flows required for public health and stream sanitation needs are recommended by this report and should be provided wherever feasible.

The States in this area have made considerable progress in pollution abatement and all have promoted the installation of adequate treatment facilities. However, statutory backing with effective laws is a definite need. Another handicap has been the lack of a sufficient number of competent technical personnel on the staffs of the health departments. Present key personnel are experienced and capable but cannot handle, unaided, the work load throughout the Sub-Basin.

The Montana water pollution control agency is making progress towards securing an adequate staff of technical personnel but still needs adequate statutory backing and should have the full support of the State legislature. The authority of the water pollution control agency should be broadened to encompass all water uses.

The North Dakota State Department of Health, although long active in pollution control and abatement, has need for adequate supporting law and sufficient funds to secure personnel commensurate with the problems encountered. The existing legislation in South Dakota, although subject to certain defects, has been used effectively in the past and much can be accomplished under the current legislative statutes.

The State Department of Public Health of Wyoming has recently secured passage of legislation broadening the field of interest over which it has purview in water pollution control. It appears that this latter measure will permit the development of an adequate comprehensive program.

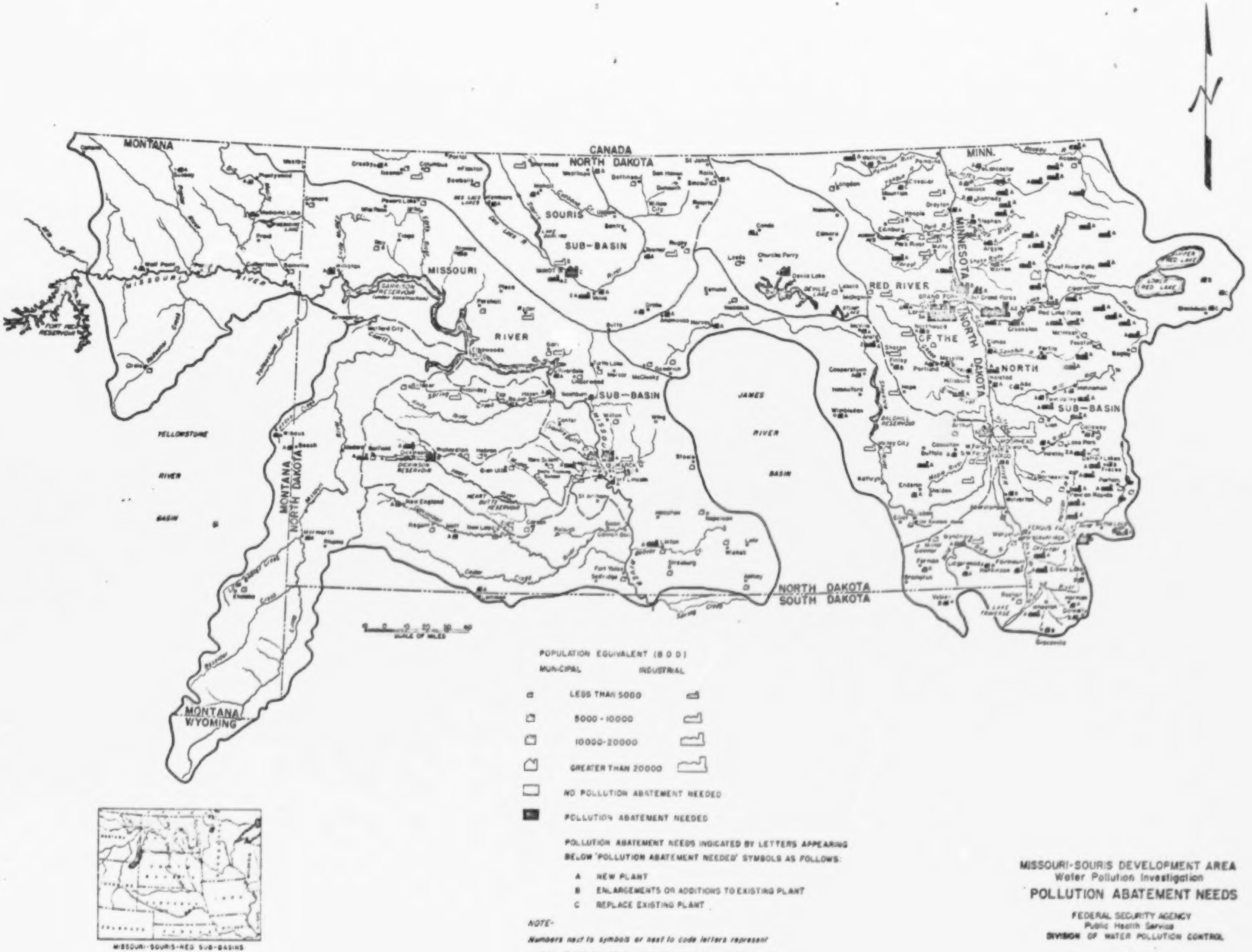
The Minnesota Department of Health has received legislative support in passage of a Water Pollution Control Act and is making progress in development of a competent staff of technical personnel.

Sewage treatment needs as specified in the Missouri River Sub-Basin section should be obviated. Generally, the sources of pollution are not great in size and they are separated by considerable distances which minimize their effects. There is no critical interstate pollution problem on the main stem of the Missouri River.

The Souris Sub-Basin lies within the State of North Dakota. The sewage and waste treatment needs as set forth in that Sub-Basin section should be provided for by the communities and industries involved. Here the water resources development program may permit an increase in sustained minimum flows which will do much to benefit stream sanitation.

The Red River Sub-Basin includes parts of South Dakota, North Dakota, and Minnesota. It is in this Sub-Basin where pollution control and abatement appears to be most critical and where an interstate problem exists. Sewage treatment needs have been listed in the Red River Sub-Basin section and water pollution control works should be installed where indicated. Pollution discharged to the Red River below Wahpeton-Breckenridge, where the stream forms the boundary between North Dakota and Minnesota, is a matter of interstate concern. The States have recognized the need of cooperative approach to this situation and have endeavored to solve the problem formally in the establishment of the Tri-State Waters Commission, and informally by use of an Interstate Sanitation Committee. The Tri-State Waters Commission is not an active body and the informal Interstate Sanitation Committee is operating but lacks an official status. A more effective cooperative agreement between the States bordering the Red River may be necessary before a satisfactory solution can be secured. There appears to be added incentive for the establishment of an effective agency to control water pollution in the Red River Basin, so that advantage may be taken of the possibility that present stream discharges in the Sheyenne and lower Red River may be augmented by importation of water from the Missouri River. In the light of present development it appears that it will be necessary, if such flows are to be secured, that payment for such waters be made similar to those charged for irrigation water. It will be noted in the Red River Sub-Basin section that increased minimum stream discharges will be beneficial in permitting a lesser degree of waste treatment or additional water uses under high degrees of waste treatment. To derive these benefits, however some means must be devised whereby payment may be collected from the beneficiaries, including communities, industries, and possibly, to a certain degree, the general public in the States concerned.

FIGURE 6


N
MONTANA
CANADA
NORTH DAKOTA
MINN.
SOURIS
SUB-BASIN
MISSOURI
RIVER
SUB-BASIN
RED RIVER
OF THE
NORTH
SUB-BASIN
MINNESOTA
NORTH DAKOTA
JAMES
RIVER
BASIN
YELLOWSTONE
RIVER
BASIN
MONTANA
NORTH DAKOTA
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
FORT PECK RESERVOIR
GARRISON RESERVOIR
DEVILS LAKE
UPPER RED LAKE
LOWER RED LAKE
SCALE OF MILES
POPULATION EQUIVALENT (B O D)
MUNICIPAL
INDUSTRIAL
LESS THAN 5000
5000 - 10000
10000-20000
GREATER THAN 20000
NO POLLUTION ABATEMENT NEEDED
POLLUTION ABATEMENT NEEDED
POLLUTION ABATEMENT NEEDS INDICATED BY LETTERS APPEARING BELOW 'POLLUTION ABATEMENT NEEDED' SYMBOLS AS FOLLOWS:
A NEW PLANT
B ENLARGEMENTS OR ADDITIONS TO EXISTING PLANT
C REPLACE EXISTING PLANT
NOTE-
Numbers next to symbols or next to code letters represent number of pollution abatement needs in the category designated
MISSOURI-SOURIS-RED SUB-BASINS
LOCATION MAP

MISSOURI-SOURIS DEVELOPMENT AREA
Water Pollution Investigation
POLLUTION ABATEMENT NEEDS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

STREAM FLOW REGULATION AND SEWAGE TREATMENT REQUIREMENTS

The water resource development program will have far reaching influences upon residents of the region. It proposes to provide a stream at places where no river previously existed, to make available an adequate supply of water where there has been but small intermittent flows, and to supplement existing inadequate stream flow. It may stabilize ground water levels.

Benefits Attributable to Flow Regulation

Tangible and intangible benefits resulting from flow regulation are many and widespread. A firm source of public and industrial water supply where none previously existed or where the present supply is inadequate is of tremendous economic value. Reduced operating costs at municipal and industrial water treatment plants may be experienced. Sewage treatment costs may be reduced. Fish and wildlife conservation and recreational developments will be improved. Intangible values, although difficult to evaluate, may even overshadow those benefits readily determined on a monetary basis. The sanitary improvement of an environment will bring about an improvement in general public health which in turn results in better enjoyment of living, increased longevity, and increased production per capita.

Tangible monetary benefits, and in some cases damages, affecting sewage disposal programs of various cities attributable to the flow regulation program may be evaluated in numerous instances. The proper relationship between sewage treatment and minimum sustained stream slows should produce stream conditions that will prevent public health hazards and nuisances and maintain balanced aquatic life. It should be possible to plan for regulated minimum flows in this development area so that maximum beneficial use may be achieved from water resources.

The drought of the thirties emphasized the importance of water and man's dependence upon it for his existence. During critical dry periods, many tributaries of the Red River ceased to flow and even the Red River had extended periods of no flow. These low flow conditions were especially serious to communities using surface waters as sources of public water supply because of the resulting limited quantity and lowered quality of water available. Also, ground water sources in many instances failed, had reduced yields, or produced water of undesirable quality. Lack of suitable existing water supply sources for municipal, industrial, and rural use makes creation of a firm water source of great value. Geological investigations have indicated with a reasonable degree of certainty that ground water sources can not be relied upon to meet the increasing water requirements for the enlarging municipalities and potential industrial development in this area.

The value of a source of water to a community or individual is most difficult to evaluate. Obviously, the dependence of life and progress upon a firm sustained water supply is basic. However, evaluation is complicated by the fact that there is no alternate source whereby the cost of developing the alternate supply might be compared to the value of the increased flow. Yet, Fessenden, North Dakota, spent about $250 per capita developing a water supply that is not entirely adequate. Moorhead, Minnesota, spent an estimated $25 per capita developing a supplemental supply. The "Nationwide Inventory of Sanitation Needs" published by the U. S. Public Health Service, 1946, estimates the per capita cost of new water works systems needed in the State of North Dakota at $125 and in Minnesota at $235. Taking these and other factors into consideration, it appears reasonable to assume a conservative average value of a water supply will approach $100 per capita depending upon the local conditions involved. On this basis a total per capita cost for benefits of the firm supply may be estimated. Assuming a useful life for amortization and an interest rate, the annual benefit figure may be derived.

The population for which these benefits can be calculated is in communities not previously provided with an adequate supply of water, in communities which may beneficially use water provided by the development program, and possibly in rural areas where ground water levels may be stabilized. The latter group would be the most difficult to enumerate.

Additional benefits might accrue to the flow regulation program as a result of the reduced cost of softening water, due to releases of lower hardness water which was stored during periods of runoff. A number of investigators have studied benefits due to water softening. Applebaum[1] writes that $44 a year per family of five which formerly had been lost in cost of soaps, plumbing bills, losses of fuel, decrease of life of fabrics, and increased wear of cooking utensils would be saved. Hoover[2] reported a savings of $48.42 per year per family of five when a water of 70 ppm. was used instead of 270 ppm. He presented data to substantiate claims that a family could have afforded to pay five to six times the existing water rates and that softening would have cost one-eighth the cost of soap wastage. These figures do not include savings to industry made possible by water softening. Estimates of the cost of softening vary from 75 cents to $2.00 per million grains[3] of hardness removed in addition to the fixed charges which may approach $2.50 per million gallons when the water softening features are incorporated in the design of a rapid sand filter plant. Softening benefits may readily be estimated by taking into consideration reduced hardness and volume of water utilized.

The availability of a firm source of good water is of added value in itself. Industries such as sugar beet factories and packing plants requiring large volumes of water desire to locate in the Red River Sub-Basin mainly along the main stem but cannot because of water supply demands and partly because of the need for waste dilution water. Industrial expansion benefits are tremendous but can not be reasonably estimated at this time.

The Corps of Engineers in their "Report on Survey of Red River of the North Drainage Basin"[4] utilized an ingenious method of evaluating water supply benefits of increased sustained flows by considering, on a point basis, various factors such as quantity, hardness, availability, and general quality. This method is discussed more in detail in the Red River Sub-Basin section.

[1] Water Works Engineering, Volume 85, No. 15, July 27, 1932.

[2] National Lime Association, Bulletin 211.

[3] 17.1 ppm. equal 1 grain.

[4] Report on Survey of Red River of the North Drainage Basin, Minn., S. Dak. and N. Dak. for Flood Control and Other Purposes - War Department, Corps of Engineers, 24 September 1947.

The maintenance of minimum flows in the streams of the Basin to provide adequate sewage dilution at all times as discussed later will be the controlling factor in the quantity of water that can be used or is needed for sanitation purposes in the area. Yet there is a critical and immediate need for an increased minimum flow of water for water supply purposes.

Sewage Treatment Requirements

Generally, critical pollution will be abated by the water pollution control agency of the State in the interest of public health, stream sanitation, and prevention of nuisances. Undesirable conditions may be alleviated by installation of sewage and industrial waste treatment plants designed to relieve pollutional loads discharged to the stream. Treatment required will depend upon the nature and site of contributed wastes, flow conditions, and downstream water uses. Primary treatment for removal of settleable solids and floating matter has been regarded by the State water pollution control agencies as a minimum requirement. When normal minimum stream flows are below the limit needed for adequate assimilation of primary treated effluents, secondary or a higher degree of treatment becomes necessary. Lagoons have been effectively used for a high degree of waste treatment at many locations in the area. Downstream uses, such as public water supply, irrigation, ice harvesting, and recreation, may necessitate a high degree of treatment with chlorination of final effluent.

Streams flowing through uninhabited areas carry organic material which causes a measurable pollutional effect as gauged by its oxygen consuming powers. This residual amount of pollution is usually augmented by runoff from farming and livestock areas. Surface wash from both urban and rural regions is difficult to evaluate due to numerous substances which enter this water from each area. Various characteristics of the watershed and its uses are implicated. Among these are location, size, shape, slope, and surface conditions such as cover and perviousness of the soil. The type of area, urban or rural, and farming practices, especially those pertaining to fertilization, are important. In some specific reaches, wastes from concentrations of waterfowl may have an appreciable effect upon the stream, especially around wildlife refuges which occur in various sections of the area under consideration. However, during periods of low flow, surface pollution is at a minimum and sources of concentrated municipal and industrial pollution usually become the major factors in determination of waste treatment requirements and flow needs at critical locations. Wastes from wildlife may be significant at specific locations where they may exert an appreciable oxygen demand during critical winter conditions when streams are covered with ice. In these studies efforts have been made to evaluate the above factors.

Modification of flow patterns in the area resulting from the development plan introduces various possibilities. Decrease in flow caused by storage or diversion may necessitate a higher degree of sewage treatment while, on the other hand, higher minimum flows may permit a lesser degree of sewage treatment. Utilization of impounded waters for dilution purposes is subject to a number of complicating factors. In the summer, loss in stream flow may be occasioned by evaporation, transpiration, diversion for irrigation, and percolation to ground water. Thus, reservoir releases may be substantially reduced by these losses before the point of pollution is reached. During winter months, reservoir releases must provide for water retained by ice formation in addition to those needed to maintain flows. Evaluations of flow do not include the above factors and figures presented represent stream flow for effective dilution at points of pollution.

Return of irrigation waters may provide minimum desired flows at certain times of the year. However, in order to achieve a beneficial value from return flows, it will be necessary that they, supplemented by any other possible flows, provide the minimum recommended stream discharges throughout the year.

During open water periods stream flow requirements increase with water temperature. Ice cover, due to its interference with aeration and photosynthesis, often permits complete deoxygenation of water beneath, and may lead to undesirable conditions during winter months if sufficient dilution flows are not provided. Hence, highest dilution flows will be required during the summer and winter seasons.

Natural Self-Purification - Knowledge of the self-purification capacity of streams has been utilized to ascertain the amount of pollution the stream can assimilate without serious impairment of its dissolved oxygen level. The required degree of sewage treatment can then be selected.

Oxygen level in any stream is inconstant, and depends upon the relative intensity of oxygen-supplying and oxygen-consuming processes. Oxygen is depleted by aerobic decomposition of organic materials and respiration of aquatic organisms, the rate being determined by concentration of organic wastes and aquatic organisms, volume of flow, time of day, and water temperature. Oxygen is supplied by absorption from the atmosphere and by photosynthesis of algae and other aquatic plants. Quantities dissolved from the air are influenced by atmospheric pressure, percentage of saturation in the water, amount of water surface exposed, degree of turbulence, and water temperature. Algal growths are largely determined by inorganic compounds in solution, composition of stream bottom, and depth of effective light penetration. Photosynthesis occurs only in the presence of light and thus may be severely restricted in highly turbid waters. Plant growths may induce supersaturated oxygen levels during daylight hours, but they consume oxygen at night; therefore it is frequently necessary to balance their oxygen consumption against their oxygen production in order to correctly evaluate their benefit to a stream.

Stream self-purification may be materially affected by the installation of a stream barrier, or dam. The velocity of flow through the reservoir behind a dam is often quite low, resulting in deposition of a portion of the organic pollution load, thus a higher percentage of the effects of the flowing load is exerted over the relatively short mileage of the reservoir. Slower velocities reduce mixing and therefore lessen reaeration, but quiescent conditions are favorable to plankton algal growth and photosynthesis since, at slower velocities, turbidity will be reduced. Finally, passage of water over tailrace and spillway results in greater mixing and increased aeration.

Recommended Flows - Recommended desirable minimum stream flows are those required to assimilate the residual organic matter from designated treatment processes without lowering the dissolved oxygen level below that required for balanced aquatic life. They should be maintained wherever possible by a flow regulation program. Desirable primary treatment flows have been based upon a minimum of efficient primary treatment (35 percent B.O.D. removal), and a 5 ppm. dissolved oxygen residual in the stream. Desirable flows for secondary treatment assume efficient operation of secondary treatment facilities (a minimum of 75 percent B.O.D. removal), and a minimum of 5 ppm. dissolved oxygen in the stream. Winter temperatures and ice cover have been considered in determining these desired flows. Flow presentations include those for: (1) existing pollution; and (2) the wastes that will be produced by the estimated population and industrial development in the year 1980. The latter figure may approach that representing ultimate development although it is fully realized that these increases may not materialize until some time after 1980. Desirable flows suggested in this report provide for minimum sanitation needs of the stream. A higher degree of sewage treatment and/or increased minimum stream flows may be used to offset the effects of greater domestic and industrial pollution and in event higher uses of the stream develop.

Minimum Flows - The foregoing discussion deals with desirable flows. In some locations the normally expected unregulated minimum flow is more than adequate to assimilate partially treated sewage without serious oxygen depletion. Normal minimum flow may be defined as the lowest mean monthly stream discharge occurring at such a frequency as to form a firm basis for sewage treatment design. It has been taken in this report as the minimum mean monthly flow expected to occur once in ten years because of stream conditions and water use. At other locations normal minimum flows may be insufficient to adequately assimilate pollution loads without the highest possible degree of sewage treatment. Experience has shown that, even with the highest degree of treatment, it is difficult to maintain satisfactory conditions in a stream below points of pollution where periods of extremely low or zero flow are encountered quite frequently. It is not sufficient, however, to maintain minimum flow conditions by regulation on the assumption that the resulting stream would be no worse than prior to reservoir and irrigation development. Actually stream conditions would be more unsatisfactory most of the time and would be no worse only at times of normally expected unregulated low flow.

Treatment Requirements - Treatment requirements are based upon normal minimum flow expectancies and self-purification capacities of streams. In this fashion economic use is made of flowing bodies of water besides protecting, over reasonable periods of time, sanitary quality of the stream. Water scarcity indicates the need of sewage treatment of greater efficiency than customary secondary treatment, since removal of all oxygen consuming substances may often be desirable. Recourse to tertiary treatment has furnished 90 to 95 percent B.O.D. removal in some instances. If these minimum expected flows are raised by a flow regulation program, benefits to cities may result from a lower required degree of treatment. On the other hand, if present normally expected low flows are reduced by such a program, cities may be damaged to the extent that a higher degree of sewage treatment may be necessary to maintain satisfactory oxygen conditions in the stream. Where studies indicate that basic minimum primary treatment requirements for all cities are adequate at present minimum flows, there can be no benefits ascribed to increase of minimum flow levels by regulation. Where regulation may alter flows so that communities may change their present sewage disposal practices, requirements for municipalities should be revised.

Evaluation of Flow Regulation

Refinement beyond primary treatment (where stream flow is low or zero at times, secondary treatment may be taken as the base) represents a substantial financial investment and introduces possible benefits where stream flow can be increased to permit satisfactory stream conditions with a lesser degree of treatment, thereby effecting a sizable saving in initial plant cost as well as in operation, maintenance, and replacement. This saving is considered a direct benefit from the increase in stream discharge. Such a benefit may reach considerable proportions when a river receives successive discharges of many communities and industries.

Benefits that may result from various flow situations have been assigned a monetary value based upon estimated annual costs of sewage treatment. Per capita costs of treatment plant construction have been varied according to size of city and degree of treatment as reflected by cost data derived from this area. Initial costs have been expressed as annual charges covering a 20-year life and 4 percent interest rate. Annual per capita costs of operation and maintenance have been included.

Primary treatment is inadequate for municipalities and industries discharging to a stream having a normally expected minimum monthly average flow below the desirable flow, and a higher degree of treatment is required. In these cases primary treatment would be adequate if a regulation program provided a minimum monthly average flow equal to or greater than the desirable flow. Benefits would result from savings realized from a lower degree of treatment. No benefits are possible when the normally expected minimum flow is equal to or greater than the desirable flow corresponding to primary treatment. Where normally expected minimum monthly average flow is equal to or greater than the desirable flow, primary treatment may be adequate. Should the flow regulation program provide a minimum flow less than the desirable flow, a higher degree of treatment will be necessary with resultant increased costs to the city. However, no damages will occur when regulated flow is greater than desirable flow, even though it represents a reduction of the normally expected minimum flow.

Flow Requirements for Future Populations

The water resource development plan visualized for this area is a long range program and evaluations of water use encompass a considerable length of time. Future ultimate flow requirements for water supply and sanitation would be of importance to water management in the development of the program. It has been assumed that this value might be approached in 30 years.

An evaluation of the future sewered population equivalent discharged from sewage and waste treatment plants has been based upon the following factors: (a) the entire population in a metropolitan area will be tributary to sewerage; (b) the population will increase; (c) the industrial activity will increase the amount of pollution contributed from this source; (d) the use of sewerage to dispose of household food wastes (garbage grinder) may increase the tributary domestic pollution approximately 20 percent. The latter factor has only recently been of concern in the design of sewage treatment works. One city in Indiana is reported to have abandoned its existing garbage disposal system in favor of household garbage grinders. It is believed that this trend will continue. Many reports in recent years have indicated that the additional load on the sewage treatment plant is not difficult to handle. The net effect of the above increases, it has been assumed, will be to double the present pollution load.

It is also reasonable to assume that over the 30-year period the efficiency of sewage treatment and sewage treatment equipment will improve, especially as influenced by operation. The assumption is made that future treatment, with additional treatment refinements and improved operation, may increase the removal of pollution over the presently assigned dependable values by 10 percent. On this basis, secondary treatment will provide approximately 85 percent and primary treatment 45 percent removal of the biochemical oxygen demand prior to discharge to watercourses.

However, there may be numerous instances where excessive population growth and significant industrial development will exceed the estimated increments. In these cases a substantially greater pollutional load may be placed upon treatment facilities and receiving streams. As it is impossible at the present time to clearly evaluate these conditions, recourse to study of these individual problems as they occur will be necessary. It appears that competent sewage plant design using as a basis the present stream flows designated as desirable, and adjusting for population increases, would suffice for conditions encountered in the near future, as the average life of a treatment installation is 20 years. Special conditions such as the development of additional industrial activity, establishment of a new industry, or large increases in population, would necessitate a special study of the area concerned.

Dam and Reservoir Effect on Pollution Assimilation

Impoundments serve to reduce organic pollution which enters the storage basin. Decreased velocities permit sedimentation; additional detention time enables biological action to reduce organic wastes; and clarification permits development of algal growths. However, sedimentation of organic wastes could cause localized nuisances due to development of sludge banks which would use the dissolved oxygen available in waters of the reservoirs. Reaeration of a high degree is effected when flow passes over spillways and tailraces. The oxygen acquired in this manner adds to the assimilative capacity of a stream.

Effect of Reservoir Backwater - The construction of reservoirs requires consideration of backwater and its possible effects upon local programs of sewage disposal. Backwater may inundate sewage plants and appurtenances, or reduce the velocity of the stream, thereby enhancing sedimentation with the possibility of creating local nuisances.

MISSOURI RIVER SUB-BASIN

TABLE OF CONTENTS

Page

Summary 85
Conclusions 86
Description 86
Water Resource Development 89
    Existing Projects 89
    Potential Development Projects 89
Presentation of Data 93
    Municipal Water Supplies 93
    Industrial Water Supplies 95
    Pollution Contributed to Water Resources 96
    Low Flow Frequencies 96
    Laboratory Results 96
Discussion 100
    Municipal Water Supplies 100
    Industrial Water Supplies 103
    Irrigation Water 103
    Sources of Pollution and Status of Sewage Treatment 103
    Stream Conditions 104
    Sewage and Waste Treatment Needs 109
    Flow Needs Evaluation 111

Preceding page blank

TABLES AND FIGURES

Table

Table		Page
M-1	Principal tributaries and their drainage areas	87
M-2	Population of municipalities	88
M-3	Development program dams	90
M-4	Municipal surface water supplies	93
M-5	Municipal ground water supplies	94
M-6	Industrial ground water supplies	95
M-7	Basic data on sources of municipal pollution	97
M-8	Basic data on sources of industrial pollution	98
M-9	Probable frequency of low mean monthly flows	99
M-10	Dissolved oxygen at Bismarck, North Dakota	101
M-11	Communities which may derive water supply benefits by existing and proposed impoundments and diversions . .	102
M-12	Existing municipal sewage treatment facilities	103
M-13	Adequacy of existing waste treatment facilities . . .	104
M-14	Project list	108
M-15	Municipal and industrial waste treatment needs	109
M-16	Status of municipal and industrial action on pollution abatement needs	110
M-17	Progress in pollution abatement	111
M-18	Flow needs at given locations and cost evaluation . . .	112
M-19	Flow needs in c.f.s. by months for critical locations .	114

Figure

Figure		Page
M-1	Sources of Pollution	98

SUMMARY

The section of the Missouri River watershed covered in this report includes 49,700 square miles between the mouths of Milk River in Montana and Spring Creek in South Dakota, exclusive of the Yellowstone River. Agriculture, principally livestock raising and small grain farming, sustains the economy of this Sub-Basin. Although it is underland with large quantities of lignite coal and appreciable quantities of oil, little has been done to develop these resources until recently. Only four of the region's 117 communities have populations exceeding 5,000, the majority of the remainder have less than 500. The Sub-Basin's population is estimated at 221,460.

The lack of water, except in the main stem of the Missouri River, has restricted development. Existing water uses include public water supplies, irrigation, ice harvesting, stock watering, wildlife propagation, and recreation. Resource development plans in this Basin include existing Dickinson and Heart Butte Dams; Garrison Dam which is under construction; potential Medicine Lake, Broncho, Thunderhawk, and Cannonball reservoirs. The backwaters of the reservoir to be formed by Oahe Dam on the Missouri will extend well into this area. The development will enhance legitimate water uses.

Eight municipal surface supplies serve an estimated 42,700 people. Forty-nine municipalities serving about 36,370 persons utilize ground water sources. Twenty industries also have private ground water supplies.

Sources of municipal and industrial pollution are not great. The population equivalent of waste discharged to municipal systems, including 18,000 contributed by industry, equals that of 98,000 people. Treatment reduces the strength of these wastes by about 16 percent. Industrial waste produced by 14 plants with separate discharges has a population equivalent of 5,210; treatment effects an over-all reduction of 25 percent before discharge to watercourses. Four industries produce primarily inorganic wastes.

Twenty-one municipal sewage treatment projects are required, of which 19 are entirely new installations and 2 are additions. Six industries need new plants. Cost of constructing the new facilities and improvements is estimated at $2,750,000.

Seventeen new sewage treatment works were installed between 1946 and 1951. No new industrial plants were constructed during these six years. Progress, stimulated by action of State water pollution control agencies, may be anticipated in the near future. Annual tangible benefits exceeding $43,460 may possibly accrue to water regulatory projects because of savings in waste treatment costs if minimum flows recommended in the report can be provided. Estimates of the benefits to be derived by each municipality from increased flows are listed in table M-18. The water requirements upon which the benefits are based are shown in table M-19.

CONCLUSIONS

1. The economy of the region is dependent upon water resource conservation and development. Such measures will increase availability of water supplies and improve water quality.

2. Municipal water supplies are derived from wells except for seven cities located on the main stem of the Missouri, and Dickinson, North Dakota, on the Heart River.

3. There is need for additional sewage treatment plants and improvement in existing works before pollution is arrested. Nineteen new plants and improvements to two existing municipal treatment plants are considered necessary. Six new industrial waste treatment works are needed.

4. The effects of pollution are usually local, damaging streams for fish propagation, natural ice, and livestock watering and creating nuisances. Interstate pollution is insignificant.

5. Stream flows are erratic and undependable sources of dilution water under natural conditions in most streams except the Missouri River.

6. Flow regulation resulting from the water resources development program may reduce sewage treatment cost to two municipalities on the Heart River if adequate flows can be provided (table M-18). Reduction in existing normal low flows on the Knife River could possibly cause damages to three cities.

DESCRIPTION

The Missouri River Sub-Basin as designated in this report is the area drained by the Missouri River from below the mouth of the Milk River in Montana to Spring Creek in South Dakota, exclusive of the Yellowstone River. This Sub-Basin encompasses approximately 49,700 square miles of which 32,560 are in North Dakota; 15,630 in Montana; 800 in South Dakota; and 710 in Wyoming. The major tributaries of the Missouri River in this Sub-Basin are the Poplar, Big Muddy, Little Missouri, Knife, Heart, and Cannonball. Table M-1 lists the principal tributaries and their drainage areas.

SUMMARY

The section of the Missouri River watershed covered in this report includes 49,700 square miles between the mouths of Milk River in Montana and Spring Creek in South Dakota, exclusive of the Yellowstone River. Agriculture, principally livestock raising and small grain farming, sustains the economy of this Sub-Basin. Although it is underland with large quantities of lignite coal and appreciable quantities of oil, little has been done to develop these resources until recently. Only four of the region's 117 communities have populations exceeding 5,000, the majority of the remainder have less than 500. The Sub-Basin's population is estimated at 221,460.

The lack of water, except in the main stem of the Missouri River, has restricted development. Existing water uses include public water supplies, irrigation, ice harvesting, stock watering, wildlife propagation, and recreation. Resource development plans in this Basin include existing Dickinson and Heart Butte Dams; Garrison Dam which is under construction; potential Medicine Lake, Broncho, Thunderhawk, and Cannonball reservoirs. The backwaters of the reservoir to be formed by Oahe Dam on the Missouri will extend well into this area. The development will enhance legitimate water uses.

Eight municipal surface supplies serve an estimated 42,700 people. Forty-nine municipalities serving about 36,370 persons utilize ground water sources. Twenty industries also have private ground water supplies.

Sources of municipal and industrial pollution are not great. The population equivalent of waste discharged to municipal systems, including 18,000 contributed by industry, equals that of 98,000 people. Treatment reduces the strength of these wastes by about 16 percent. Industrial waste produced by 14 plants with separate discharges has a population equivalent of 5,210; treatment effects an over-all reduction of 25 percent before discharge to watercourses. Four industries produce primarily inorganic wastes.

Twenty-one municipal sewage treatment projects are required, of which 19 are entirely new installations and 2 are additions. Six industries need new plants. Cost of constructing the new facilities and improvements is estimated at $2,750,000.

Seventeen new sewage treatment works were installed between 1946 and 1951. No new industrial plants were constructed during these six years. Progress, stimulated by action of State water pollution control agencies, may be anticipated in the near future. Annual tangible benefits exceeding $43,460 may possibly accrue to water regulatory projects because of savings in waste treatment costs if minimum flows recommended in the report can be provided. Estimates of the benefits to be derived by each municipality from increased flows are listed in table M-18. The water requirements upon which the benefits are based are shown in table M-19.

Table M-1. Missouri River Sub-Basin - Principal tributaries and their drainage areas

Stream	Miles above mouth Missouri River	Drainage area square miles
Missouri River (Spring Creek, S.D., to Milk River, Mont.)		49,700*
Redwater Creek	1,777.8	2,107
Poplar River	1,775.8	3,270
Big Muddy Creek	1,725.7	2,870
Little Muddy Creek	1,643.4	1,020
Little Missouri River	1,506.8	9,500
Knife River	1,440.6	2,625
Painted Woods Creek	1,412.6	628
Heart River	1,373.3	3,400
Apple Creek	1,365.1	613
Cannonball River	1,333.4	4,300

*Estimated

Populations of 117 communities in the Missouri Sub-Basin are listed in table M-2. Four cities in North Dakota have populations exceeding 5,000: Bismarck, 18,640; Dickinson, 7,469; Williston, 7,378; and Mandan, 7,298. The median population of the remaining municipalities is less than 500. Population losses that have been experienced in rural areas have been offset by concomitant gains in urban centers. The population of the Sub-Basin is estimated at 221,460.

The Sub-Basin's economy rests upon agriculture and related industries. Livestock, small grains, and corn are major contributors to farm incomes. Large quantities of lignite coal and oil which underlie portions of the area are currently being developed and give promise of future industrial expansion. After implementation of the water and land development program, farm production and food processing industries should expand.

Climate in the Missouri Sub-Basin is fairly uniform throughout. Rainfall averages about 16 inches per year, and snowfall about 30 inches. The mean annual temperature is 40° F. with recorded extremes of -47° F. and 110° F.

Table N-2. Missouri River Sub-Basin - Population of municipalities

Municipality	Population - U. S. Census			
	1920	1930	1940	1950
Montana				
Bainville	396	471	403	356
Brockton	-	-	350	375*
Circle	-	519	685	856
Culbertson	547	536	585	779
Ekalaka	433	475	719	904
Frazier	-	-	378	500*
Froid	410	434	441	555
Medicine Lake	292	384	396	454
Outlook	295	302	208	235
Plentywood	888	1,226	1,574	1,862
Poplar	1,152	1,046	1,442	1,169
Reserve	-	-	-	300*
Scobey	1,170	1,259	1,311	1,628
Westby	253	287	369	396
Wibaux	611	619	625	739
Wolf Point	2,098	1,539	1,960	2,557
North Dakota				
Alamo	-	211	214	192
Almont	-	-	232	190
Amidon	145	141	102	82
Arnegard	-	254	222	206
Ashley	1,009	1,033	1,345	1,423
Beach	1,106	1,263	1,178	1,461
Belfield	526	653	870	1,051
Bentley	-	-	110	-
Beulah	552	913	942	1,501
Bismarck	7,122	11,090	15,496	18,640
Braddock	216	193	185	175
Cannon Ball	-	-	100	-
Carson	277	356	473	493
Center	-	293	509	492
Cole Harbor	-	-	312	315
Dickinson	4,122	5,025	5,839	7,469
Dodge	172	204	234	251
Douglas	284	288	313	236
Driscoll	-	-	235	-
Dunn Center	247	276	238	246
Elbowoods	-	-	175	-
Elgin	429	505	583	882
Epping	116	183	154	158
Flasher	287	346	387	413
Fort Lincoln	-	-	200	200*
Fort Yates	-	-	1,000	1,000*
Garrison	714	1,024	1,[illegible]17	1,890
Gladstone	-	-	278	224
Glen Ullin	875	950	976	1,324
Golden Valley	369	294	400	339
Golva	-	-	128	174
Grenora	358	487	425	525
Hague	315	364	442	328
Halliday	289	305	395	477
Hanks	-	213	192	115
Hazelton	382	446	500	453
Hazen	520	689	662	1,230
Killdeer	512	495	650	698
Lefor	-	-	138	-
Lehr	362	458	536	394
Leith	158	174	166	160
Linton	1,011	1,192	1,602	1,675
McGregor	-	-	175	-
McKinzie	-	-	125	-
Makoti	283	276	212	219
North Dakota (Cont'd)				
Mandan	4,336	5,037	6,685	7,298
Marmarth	1,318	721	626	469
Max	473	500	423	465
Medora	-	-	175	-
Mercer	-	-	250	214
Mott	723	1,036	1,220	1,583
Napoleon	554	709	982	1,070
New England	613	911	895	1,117
New Leipzig	378	443	366	447
New Salem	711	804	875	942
Palermo	179	205	178	150
Parshall	376	470	570	935
Plaza	345	408	360	389
Powers Lake	251	382	464	565
Raleigh	-	-	140	-
Ray	563	621	579	721
Regan	202	162	149	129
Regent	262	308	261	405
Rhame	302	356	283	340
Richardton	626	710	682	721
Riverdale	-	-	-	2,000*
Ross	-	-	130	-
Ryder	483	457	467	330
St. Anthony	-	-	130	-
Sanish	337	463	455	507
Selfridge	153	351	329	343
Solen	-	-	350	-
Stanley	591	936	1,058	1,486
Stanton	325	358	370	571
Steele	550	519	721	762
Sterling	-	-	200	-
Strasburg	653	695	994	733
Tagus	133	136	140	101
Tappen	182	268	323	379
Taylor	285	263	251	258
Temvik	-	-	200	-
Tioga	320	435	385	456
Trenton	-	-	159	-
Turtle Lake	395	579	632	839
Underwood	453	488	613	1,061
Van Hook	331	372	329	380
Washburn	558	753	901	913
Watford City	260	769	1,073	1,371
Werner	198	213	137	63
Wheelock	-	115	94	101
White Earth	247	240	272	218
Wildrose	449	518	472	430
Williston	4,178	5,106	5,790	7,378
Wilton	1,026	1,001	851	796
Wing	-	237	235	312
Wishek	1,003	1,146	1,112	1,241
Zahl	-	-	150	-
Zap	257	406	574	425
South Dakota				
Camp Crook	163	161	227	122
Lemmon	1,126	1,508	1,781	2,760
Morristown	269	268	217	190
Totals Montana	8,545	9,097	11,446	13,665
North Dakota	48,337	61,201	76,827	88,715
South Dakota	1,558	1,937	2,225	3,072
Grand Total	58,440	72,235	90,498	105,452

*Estimated.

WATER RESOURCES DEVELOPMENT

Existing Projects

Before inauguration of the Missouri-Souris Development Program very few large scale projects related to water use had been developed in this Sub-Basin. Seven of the eight municipalities using surface water supplies obtain them directly from the Missouri River. Some industries have constructed small impoundments on upper reaches of tributary streams.

Table 6 in the General Section shows that 3,548 acres were irrigated by an annual diversion of 4,628 acre-feet of water from the Poplar River and Big Muddy Creek. Smaller irrigation tracts exist on other tributaries, but data concerning their sizes and water use are not available. Stock watering pools and other minor impoundments on Poplar River and Big Muddy Creek have a total capacity of 2,250 acre-feet. Similar impoundments exist on other tributaries. Seven wildlife refuge impoundments on Big Muddy Creek watershed have a total storage capacity of 113,900 acre-feet.

Potential Development Projects

A review of potential water resource developments is presented to show the intricacy of the program and the over-all contemplated water use. The plan is subject to change contingent upon future developments by responsible agencies. Data on development program dams is presented in table M-3.

Under the present land and water resource conservation plan, Fort Peck Reservoir would be the major source of water supply. As soon as substitute storage is available in lower river reservoirs such as Garrison, Oahe, and Fort Randall, Fort Peck will be operated for hydroelectric power and irrigation in addition to flood control.

Fort Peck Reservoir in northeastern Montana is approximately 111 miles west of the North Dakota boundary. About 57,725 square miles of the Missouri Drainage Basin are located above the dam. The reservoir, with a maximum capacity of 19,412,000 acre-feet is 189 miles long, 16 miles wide, and 220 feet in maximum depth. As originally planned, the proposed Missouri Diversion Dam will be constructed about 22 miles downstream from Fort Peck Dam near the mouth of Little Porcupine Creek, and will control diversion to potential Missouri Canal. A definite plan report recommends the installation of proposed Little Porcupine hydroelectric power plant (18,000 kilowatts) adjacent to the diversion dam. Water released through the Fort Peck power plant will serve Missouri Canal gravity tracts and ultimately a series of pumping units in the Missouri-Souris Division. Potential Missouri Canal, which will extend eastward along the north side of the Missouri Valley to a terminus on the Poplar River, will furnish water for the Frazer-Wolf Point Indian Irrigation Unit, five new irrigation areas totaling about 100,000 acres, and for municipal water supplies at Wolf Point and Poplar, Montana. On the south side of the Missouri River, a second canal originating at the diversion dam will provide water for 7,930 acres in scattered tracts extending from the dam to the vicinity of Wolf Point. The original plan

Table M-3. Missouri River Sub-Basin - Development program dams[1]

Name	Tributary	River Mileage Main Stem	River Mileage Tributary	Irrigation	Flood Control	Water Supply	Pollution Abatement	Recreation	Fish and Wildlife	Silt Control	Power	Navigation	Total Capacity Acre-feet	Status[2]
Fort Peck Dam	Main stem	1868.7		X	X	X	X	X	X	X	X	X	19,412,000	E
Missouri Diversion Dam	Main stem	1847		X	-	X	X	X	X	-	X	-	-	P
Garrison Dam	Main stem	1455		X	X	X	X	X	X	X	X	X	23,000,000	U
Broncho Dam	Knife	1440.6	68	X	X	X	X	X	X	X	-	-	60,000	P
Dickinson Dam	Heart	1373.3	205	X	-	X	X	X	X	X	-	-	9,056	E
Heart Butte Dam	Heart	1373.3	103.5	X	X	-	X	X	X	X	-	-	350,500	E
Cannonball Dam	Cannonball	1333.4	162	X	X	X	X	X	X	X	-	-	428,000	P
Thunderhawk Dam	Cannonball-Cedar	1333.4	Ca-75.4 Ce-87	X	X	X	X	X	X	X	-	-	-	P

[1] Data from Bureau of Reclamation

[2] Status - E - Existing
P - Proposed
U - Under construction

proposes that the Missouri Canal provide water for Medicine Lake Reservoir, which will extend eastward to near Grenora, North Dakota. Water thus stored and regulated in proposed Medicine Lake Reservoir would be lifted by a pumping plant near Grenora into the Souris Canal. Much of the power needed for this lift would be generated by proposed hydroelectric plants located at drops in the canal near Crosby and Kenmare, North Dakota. Water transported by the Souris Canal could make possible the irrigation of considerable acreages in the Crosby-Mohall Unit, the New Rockford Unit, the Jamestown Unit, and the Oakes Unit.[1]

Under the ultimate plan, a number of smaller river bottom areas extending along the south bank of the Missouri River below Wolf Point, and some larger areas in the vicinity of Medicine Lake and Bainville, will obtain irrigation water from the Missouri River. The Montana Pumping Division consists of units scattered along the Missouri River from Fort Peck Reservoir to the Montana-North Dakota state line. Each of the 16 units, totaling some 35,000 arable acres, lies in a separate loop of the river, and will require individual pumping and distribution units.

The North Dakota Pumping Division consists of 15 separate units, totaling approximately 69,000 acres, scattered along the course of the Missouri River in North Dakota. These units will be irrigated by pumping from the Missouri River or from backwaters of Garrison and Oahe Reservoirs.

Garrison Dam, which will be the world's largest rolled-fill earth embankment, is located on the Missouri River approximately 75 miles northwest of Bismarck, North Dakota. The dam will stretch for more than two miles across the river valley and rise more than 200 feet above the stream bed. At maximum normal operating pool level the reservoir will contain 23,000,000 acre-feet of water in a lake 214 miles long and 14 miles wide. Garrison Reservoir will impound flood waters and provide their controlled releases for hydroelectric power, navigation, irrigation, public water supplies, sanitation, and also provide facilities for recreation and wildlife preservation.

Present plans include the pumping of water from Garrison Reservoir into Snake Creek and Turtle Lake Reservoirs. Another pumping plant on Turtle Lake Reservoir would lift water onto the divide between the Missouri River Valley and the James and Sheyenne River Valleys. From the divide water would flow through a system of canals, power plants, reservoirs, and natural stream channels to reach desirable lands in east central North Dakota.[2] If both this diversion and the Missouri-Souris are constructed they may be interconnected.

A powerhouse will be constructed below the Garrison Dam downstream from the portals of five power tunnels. Ultimately planned capacity will generate 400,000 kilowatts.

---

[1] A continued description of this diversion appears in the Souris River Sub-Basin section of this report.

[2] Further discussion of the Garrison Division is included in the Souris and Red River Sub-Basin sections of this report.

About 340 miles downstream, Oahe Dam is under construction. Although located outside the Missouri-Souris area, backwater from the impoundment will reach nearly to Bismarck, North Dakota. The dam site is about six miles north of Pierre, South Dakota. At maximum operating pool level the reservoir will be 250 miles long. This unit will be of multiple purpose type similar to Garrison Reservoir.

Tentative development plans in the Little Missouri Valley include construction of a dam and irrigation of lands adjacent to the river below the dam. Another consideration is diversion of irrigation water east into the Cannonball watershed. Four dam sites have been proposed but no decision has been reached as to the one best suited for development. Multiple use will include irrigation, flood control, silt detention, recreation, and fish and wildlife conservation.

The Knife River program includes potential Broncho Dam and Reservoir and about 15,400 acres of irrigable land along the lower 37 miles of the Knife River. Of 60,000 acre-feet of water stored in Broncho Reservoir, 50,000 acre-feet will be available for irrigation. The Bureau of Reclamation is preparing a report appraising the benefits - irrigation, flood control, silt detention, and fish and wildlife conservation - expected from the Knife River development.

The Heart River development includes Dickinson and Heart Butte Dams and Reservoirs which provide water for irrigation, flood control, municipal water supply, recreation possibilities, silt detention, and fish and wildlife preservation. Dickinson Unit includes Dickinson Dam and Reservoir, located approximately two miles southwest of Dickinson, North Dakota, and 915 acres of irrigable land in the vicinity of the reservoir to be served by 7 small pumping plants. The dam, a compacted earth-filled structure with a crest height of 45 feet above the natural stream bed and a crest length of about 2,200 feet, was completed during August of 1950. The reservoir has a maximum storage capacity of 9,056 acre-feet and furnishes the City of Dickinson with a much needed water supply. Full development of irrigation will probably be deferred until low-cost power is available from Garrison Dam.

Heart Butte Unit includes Heart Butte Dam and Reservoir, about 15 miles south of Glen Ullin, North Dakota, and 13,100 acres of arable land along the Heart River between the dam and the river mouth. Heart Butte Dam, completed late in 1949, has an irrigation storage capacity of 68,700 acre-feet, silt and dead storage capacity of 6,800 acre-feet, and maximum flood control and super storage capacity of 350,500 acre-feet. In addition to irrigation, the reservoir will alleviate a serious flood hazard at Mandan, North Dakota, provide for silt detention, make possible expanded recreational facilities, and aid fish and wildlife propagation.

The Cannonball River plan consists of the Cannonball and Thunderhawk Units with provision for irrigation waters, flood control, and other beneficial water uses. The Thunderhawk Unit includes Thunderhawk Dam and Reservoir on Cedar Creek, a tributary of the Cannonball, about 25 miles south of Elgin, North Dakota. The proposed reservoir will provide water for irrigation of 8,000 acres of land along Cedar Creek. Cannonball Unit consists of Cannonball Dam and Reservoir, pumps and distribution systems for 12,400 acres of arable lands in scattered tracts along the river from the dam to the mouth of the Cannonball River. The dam, located 30 miles above the mouth of Cedar Creek, will provide flood control and irrigation storage. The reservoir will have a capacity of about 428,000 acre-feet, of which about 60,000 acre-feet will be available for irrigation. In addition to flood control and irrigation the unit will provide for silt detention, expanded recreation possibilities, fish and wildlife propagation, and possibly municipal water supplies.

PRESENTATION OF DATA

Municipal Water Supplies

Surface waters are utilized to supply eight communities (table M-4) in the Sub-Basin. Except for Dickinson, North Dakota, the cities draw upon the resources of the mighty Missouri. Dickinson is provided water by a multiple-purpose impoundment on the Heart River recently constructed as a part of the water resource development program. Culbertson, Montana, settles and chlorinates Missouri River water prior to using it. Dickinson and Fort Yates coagulate, settle, filter, and chlorinate. Bismarck, Williston, Riverdale, Washburn, and Mandan soften the water besides providing the usual coagulating, filtering, and chlorinating processes. An estimated 42,700 people are served with 4.045 million gallons daily by these municipal surface supplies, or approximately 95 gallons per capita.

Table M-4. Missouri River Sub-Basin - Municipal surface water supplies

Stream and municipality	State	Miles above mouth		Treatment[1]	Population served	Average consumption M. G. D.[3]
		Missouri River	Tributary			
Missouri River						
Culbertson	Mont.	1,715.1		SD	600	0.150
			Subtotal . . .		600	0.150
Williston	N.D.	1,644.2		DFH	6,000	0.325
Riverdale	N.D.	1,455.0		DFH	2,000	0.250
Washburn	N.D.	1,418.5		DFH	850	0.150
Mandan	N.D.	1,380.6		DFH	8,000	0.750
Bismarck[2]	N.D.	1,377.8		DFH	18,800	1.850
Heart River		1,373.3				
Dickinson	N.D.		201.3	DF	6,000	0.500
East Yates	N.D.	1,307.6		DF	450	0.070
			Subtotal . . .		42,100	3.895
			Total . . .		42,700	4.045

[1] Treatment: D - Chlorination
F - Coagulation, sedimentation, filtration
H - Softening
S - Settling

[2] Also serves Fort Lincoln - 200 population, and State Penitentiary - 320 population.

[3] State Health Department records.

Table M-5. Missouri River Sub-Basin - Municipal ground water supplies

Municipality	State	Source[1]	Treatment[2]	Population served	Average consumption M.G.D.[3]
Bainville	Mont.	W	D	350[a]	0.020
Circle	Mont.	W	N	600	0.035[a]
Ekalaka	Mont.	W	N	350[a]	0.025[a]
Medicine Lake	Mont.	W	D	350	0.020[a]
Opheim	Mont.	W	N	350[a]	0.020[a]
Plentywood	Mont.	W	H	1,200	0.070[a]
Poplar	Mont.	W	N	1,900	0.115[a]
Richey	Mont.	W	N	100[a]	0.005[a]
Scobey	Mont.	W - I.G.	N	1,000	0.060[a]
Wibaux	Mont.	W	N	600[a]	0.035[a]
Wolf Point	Mont.	W	D	1,500	0.090[a]
Subtotal				8,300	0.495
Ashley	N.D.	W	N	1,140	0.150
Beach	N.D.	W	N	1,100	0.200
Belfield	N.D.	W	N	1,250	0.050
Beulah	N.D.	W	N	1,000	0.048
Carson	N.D.	W	N	250[a]	0.014
Elbowoods	N.D.	W	N	450	0.025[a]
Elgin	N.D.	W	N	660	0.042
Garrison	N.D.	W	D	900	0.100
Glen Ullin	N.D.	W	N	900	0.060
Grenora	N.D.	W	N	520	0.060
Hazen	N.D.	W	H	1,000	0.050
Hebron	N.D.	W	N	1,300	0.090
Killdeer	N.D.	W	N	560	0.010
Lehr	N.D.	W	N	330	0.020
Linton	N.D.	W	N	1,600	0.060
Marmarth	N.D.	W	N	400	0.040
Mott	N.D.	W	N	960[a]	0.075
Napoleon	N.D.	W	N	760[a]	0.040[a]
New England	N.D.	W	N	1,000	0.090
New Leipzig	N.D.	W	N	400	0.040
New Salem	N.D.	W	N	800	0.030
Parshall	N.D.	W	D	750	0.040
Power Lake	N.D.	W	N	310	0.037
Ray	N.D.	W	N	480	0.070
Regent	N.D.	W	N	380[a]	0.035[a]
Rhame	N.D.	W	N	200[a]	0.020
Richardton	N.D.	W - I.G.	D	600	0.040
Stanley	N.D.	W	N	1,200	0.050
State Training School	N.D.	W	N	250	0.040[a]
Steele	N.D.	W	N	520	0.030
Strasburg	N.D.	W	N	450[a]	0.025[a]
Turtle Lake	N.D.	W	N	630	0.060
Underwood	N.D.	W	N	700	0.070
Watford City	N.D.	W	N	1,260	0.215
Wilton	N.D.	W	N	500	0.050
Wishek	N.D.	W	N	1,100	0.077
Subtotal				26,610	2.153
Lemmon	S.D.	W	N	1,420[b]	0.070
Morristown	S.D.	W	N	40[a]	0.002[a]
Subtotal				1,460	0.072
Total				36,370	2.720

---

[1] Source:
W - Wells
I.G. - Infiltration gallery

[2] Treatment:
D - Chlorination
H - Softening
N - None

[3] State Health Department Records.

[a] Estimated.

[b] Considered in this report to be in Cannonball drainage as sewage discharges to tributary of Cannonball.

Forty-nine municipalities obtain public water supplies from ground sources, wells, and infiltration galleries (table M-5). Approximately 2.720 million gallons per day is served to 36,370 people, or 75 gallons per capita. The water is generally distributed without treatment; 6 provide chlorination and 2 soften.

Industrial Water Supplies

Many industries secure all or part of their vital water supplies from municipal systems. Table M-6 lists 20 establishments that have private supplies for either all or a portion of their needs. These supplies are secured from ground sources. Average total daily consumption for the 20 plants is 628,400 gallons.

Table M-6. Missouri River Sub-Basin - Industrial ground water supplies

Industry	Location	Average consumption gallons per day
Armour & Co.	Sunnyside, N.D.	30,000
Armour Creameries	Bismarck, N.D.	22,000
Bismarck Abattoir Corp.	Bismarck, N.D.	4,500[a]
Bosch Meat Co.	Halliday, N.D.	1,800[a]
Enoch Schultz Creamery	Bismarck, N.D.	15,000
F. U. Co-Op Creamery	Williston. N.D.	50,000
Glen Ullin Creamery	Glen Ullin, N.D.	3,000
Hebron Co-Op Creamery	Hebron, N.D.	1,500
Lehigh Briqueting Co.	Lehigh, N.D.	-
Linton Creamery	Linton, N.D.	10,000
Linton Slaughter House	Linton, N.D.	1,000[a]
Mandan Creamery & Produce Co.	Mandan, N.D.	122,000
Mott Co-Op Creamery	Mott, N.D.	8,400
New Salem Creamery	New Salem, N.D.	2,000
Northern Hide & Fur Co.	Bismarck, N.D.	144,000
Queen City Creamery	Dickinson, N.D.	2,200
Queen City Packing Plant	Dickinson, N.D.	48,000
Ryder Co-Op Creamery	Ryder, N.D.	5,000
State Penitentiary[b]	Bismarck, N.D.	140,000
Yegen Dairy	Bismarck, N.D.	18,000
Total		628,400

[a] Estimated.

[b] Drinking water from Bismarck city system.

Pollution Contributed to Water Resources

Basic data on sources of municipal and industrial pollution are presented in tables M-7 and M-8 and depicted graphically in figure M-1. Fifty-six municipalities of the Sub-Basin have sewage systems and 1 is installing a new system. Of the existing systems, 9, or 16 percent, discharge untreated sewage; 10, or 18 percent, provide minor treatment, usually septic tanks which generally are inadequate for municipal installations; 31, or 55 percent, have primary treatment plants; and 6, or 11 percent, have secondary treatment units or lagoons that effectively treat the waste. Eighty-four percent, or 47 of the 56 systems, provide treatment as compared to a national average of 61 percent. Omitting those communities with septic tanks, 66 percent utilize reasonably effective methods.

The total population served by sewerage approximates 80,100 to which must be added the population equivalent of 17,810 contributed by industry connected to municipal sewage systems or a total waste produced equivalent to a population of 97,910. This is reduced by treatment to a population equivalent of 82,230, or by 16 percent.

Industrial waste is separately discharged by 14 establishments, of which 3 provide treatment. Six industrial establishments have waste treatment needs. The waste produced by industries having separate outlets have a population equivalent of 5,210, which is reduced by treatment to 3,890, or by 25 percent. Principal contributors of industrial waste are meat packers and milk processors.

Low Flow Frequencies

A study of stream discharges was made to ascertain probable low flow frequencies. The low mean monthly flow for summer (June-September) and winter (December-February) was selected for each of the years of record and used as a basis for establishing probable low flow expectancies (table M-9). The possible occurrence of low flows may be utilized as a basis for treatment plant design and to determine the frequency of nuisance conditions in the stream.

Data indicate that tributaries of the Missouri River experienced severe low flow conditions in the past with zero flows for prolonged periods. Most tributary streams may be considered as having zero flows frequently enough to permit the assumption of absence of flow as a firm basis for determining sewage treatment needs. The Missouri River at Williston shows 4,650 c.f.s. as the low mean summer monthly flow and 3,040 as the low mean winter monthly flow of record prior to regulation by Fort Peck Reservoir.

Laboratory Results

Since the Missouri River main stem in this area has a substantial flow (see table M-9), and present climatic conditions favor relatively high stream discharges, a sampling program was deemed unnecessary. Dissolved oxygen determinations had been previously made during the winter of 1938-39[1] when flows in many streams in the area were either greatly

---

[1] Red River of the North Research Investigation issued by the North Dakota State Department of Health.

Table M-7. Missouri River Sub-Basin. Basic data on sources of municipal pollution

Stream and municipality	Miles above mouth Missouri River	Miles above mouth Tributary	Population served by sewers	Population equivalent (B.O.D.) untreated waste[1]	Waste treatment provided	Adequacy of treatment facilities Cap'y	Adequacy of treatment facilities Oper.	Population equivalent discharged to watercourse[1]	Project needs	Current status municipal action
Missouri River										
Wolf Point, Mont.	1802.1		2,300	2,400	Minor[a]	Unsat.	Sat.	1,800	New plant	Inactive
Red Water Creek	1777.8									
Circle, Mont.		79.6	600	600	Primary	Sat.	Unsat.	(600)[c]	None	-
Poplar River	1775.8									
Scobey, Mont.		95.1	1,450	1,450	Minor[a]	Unsat.	Sat.	1,000	New plant	Inactive
Poplar, Mont.	1775.3		1,000	1,000	Primary	Sat.	Unsat.	1,000	None	-
Big Muddy Creek	1725.7									
Plentywood, Mont.		99	1,500	1,600	None	-	-	1,600	New plant	Inactive
Medicine Lake, Mont.		55	350	350	Minor[a]	Unsat.	Sat.	300	New plant	Inactive
Culbertson, Mont.	1715.1		700	700	Secondary	Sat.	Unsat.	200	None	-
Shotgun Creek	1700									
Bainville, Mont.		8	250	250	Primary	Sat.	Sat.	160	None	-
Williston, N.D.	1644.2		6,000	6,810	None	-	-	6,810	New plant	Inactive
Little Muddy Creek	1643.4									
Grenora, N.D.		52	520	520	Lagoon	Sat.	Sat.	(d)	None	-
Timber Creek	1631									
Arnegard, N.D.		22	100	100	Primary	Sat.	Sat.	(80)[c]	None	-
Beaver Creek	1590									
Tioga, N.D.		34	(450)[f]	-	(Primary)[f]	-	-	-	-	Under construction
Ray, N.D.		30	480	480	Primary	Sat.	Sat.	320	None	-
White Earth River	1579									
Powers Lake, N.D.		49	320	320	Primary	Sat.	Unsat.	(300)[b]	None	-
Little Knife River	1563									
Stanley, N.D.		83	1,200	1,320	Primary	Unsat.	Sat.	990	Addition	Inactive
Shell Creek	1525									
Parshall, N.D.		21	750	750	Primary	Sat.	Sat.	650	None	-
Little Missouri River	1506.8									
Marmarth, N.D.		306.4	400	400	Minor[a]	Unsat.	Unsat.	400	New plant	Inactive
Little Beaver Creek		306.4								
Ekalaka, Mont.		32	400	400	Secondary	Sat.	Sat.	100	None	-
Beaver Creek		137.5								
Beach, N.D.		73	1,100	1,100	Minor[a]	Unsat.	Unsat.	(1,100)[c]	New plant	Inactive
Wibaux, Mont.		62.5	500	500	Minor[a]	Unsat.	Unsat.	450	New plant	Inactive
Cherry Creek		60.5								
Watford City, N.D.		30	1,200	1,300	Primary	Sat.	Sat.	1,000	None	-
Elbowoods, N.D.	1501.5		180	180	Primary	Sat.	Sat.	120	None	-
Garrison, N.D.	1462		900	900	Primary	Sat.	Sat.	540	None	-
Riverdale, N.D.	1455		2,000	2,000	None	-	-	2,000	New plant	Inactive
Underwood, N.D.	1446		700	780	Primary	Sat.	Sat.	520	None	-
Knife River	1440.6									
Little Knife River		62								
Richardton, N.D.		60	600	600	Primary	Sat.	Sat.	(420)[e]	None	-
Hebron, N.D.		50	1,300	1,670	Secondary	Sat.	Sat.	420	None	-
Spring Creek		38.6								
Killdeer, N.D.		75.6	560	560	Primary	Sat.	Sat.	400	None	-
Zap, N.D.		11	300	300	Primary	Sat.	Sat.	200	None	-
Beulah, N.D.		32	1,000	1,000	Minor[a]	Unsat.	Unsat.	850	New plant	Inactive
Hazen, N.D.		12.5	1,000	1,000	Primary	Sat.	Unsat.	750	None	-
Stanton, N.D.		0.5	500	500	None	-	-	500	New plant	Inactive
Washburn, N.D.	1418.5		1,200	1,200	None	-	-	1,200	New plant	Inactive
Painted Woods Creek	1412.6									
Turtle Lake, N.D.		3	600	2,100	Primary	Sat.	Sat.	(1,500)[b]	None	-
Burnt Creek	1380									
Wilton, N.D.		24	500	640	Primary	Sat.	Sat.	450	None	-
Bismarck, N.D.	1377		19,000	21,700	None	-	-	21,700	New plant	Inactive
Heart River	1373.3									
Belfield, N.D.		235	1,250	1,250	Primary	Sat.	Sat.	1,000	None	-
Dickinson, N.D.		201.3	6,000	7,050	Secondary	Unsat.	Unsat.	3,500	Addition	Inactive
Antelope Creek		86								
Elgin, N.D.		28	400	400	Primary	Sat.	Sat.	(200)[c]	None	-
Carson, N.D.		16	350	350	Primary	Sat.	Sat.	(260)[c]	None	-
Muddy Creek		63								
Glen Ullin, N.D.		48	900	1,060	Primary	Sat.	Sat.	(740)[c]	None	-
Sweetbriar Creek		18.3								
New Salem, N.D.		17	800	890	Primary	Sat.	Sat.	(800)[c]	None	-
State Training School, N.D.		8	250	550	None	-	-	550	New plant	Inactive
Mandan, N.D.		7	8,000	15,000	None	-	-	15,000	New plant	Inactive
Apple Creek	1365.1									
Fort Lincoln, N.D.		9	200	200	None	-	-	200	New plant	Inactive
Cannonball River	1333.4									
New England, N.D.		274.8	1,000	1,740	Minor[a]	Unsat.	Unsat.	1,740	New plant	Inactive
Regent, N.D.		239.1	350	350	Primary	Sat.	Sat.	200	None	-
Mott, N.D.		214.7	900	1,260	Minor[a]	Unsat.	Unsat.	1,070	New plant	Inactive
New Leipzig, N.D.		171.6	400	400	Primary	Sat.	Sat.	270	None	-
Cedar Creek		75.4								
Lemmon, S.D.		95	2,300	2,300	Minor[a]	Unsat.	Unsat.	2,200	New plant	Final plans approved
Beaver Creek	1321									
Wishek, N.D.		90	1,100	1,340	Primary	Sat.	Sat.	(1,000)[c]	None	-
Napoleon, N.D.		88	250	540	Primary	Sat.	Sat.	350	None	-
Linton, N.D.		22	1,600	2,550	Secondary	Sat.	Sat.	510	None	-
Fort Yates, N.D.	1307.6		550	550	Primary	Sat.	Sat.	400	None	-
Steele, N.D.	Landlocked		480	480	Primary	Sat.	Sat.	(320)[b]	None	-
Ashley, N.D.	Landlocked		1,140	1,750	Primary	Sat.	Sat.	(1,170)[b]	None	-
Strasburg, N.D.	Landlocked		420	420	Primary	Sat.	Sat.	(320)[b]	None	-
	Total		80,100	97,910				82,230 (8,810)[e]		

[a] Septic tank.

[b] Discharge to slough--drainage to watercourse indefinite or not existent and primarily of local significance.

[c] Discharge to intermittent creek--pollution reaches watercourse only during periods of high water.

[d] Discharge to an artificial lagoon--no outlet to watercourse.

[e] Wastes generally not reaching flowing watercourses.

[f] New system - population served is not included in the column total.

[1] Includes organic industrial wastes discharging to municipal systems.

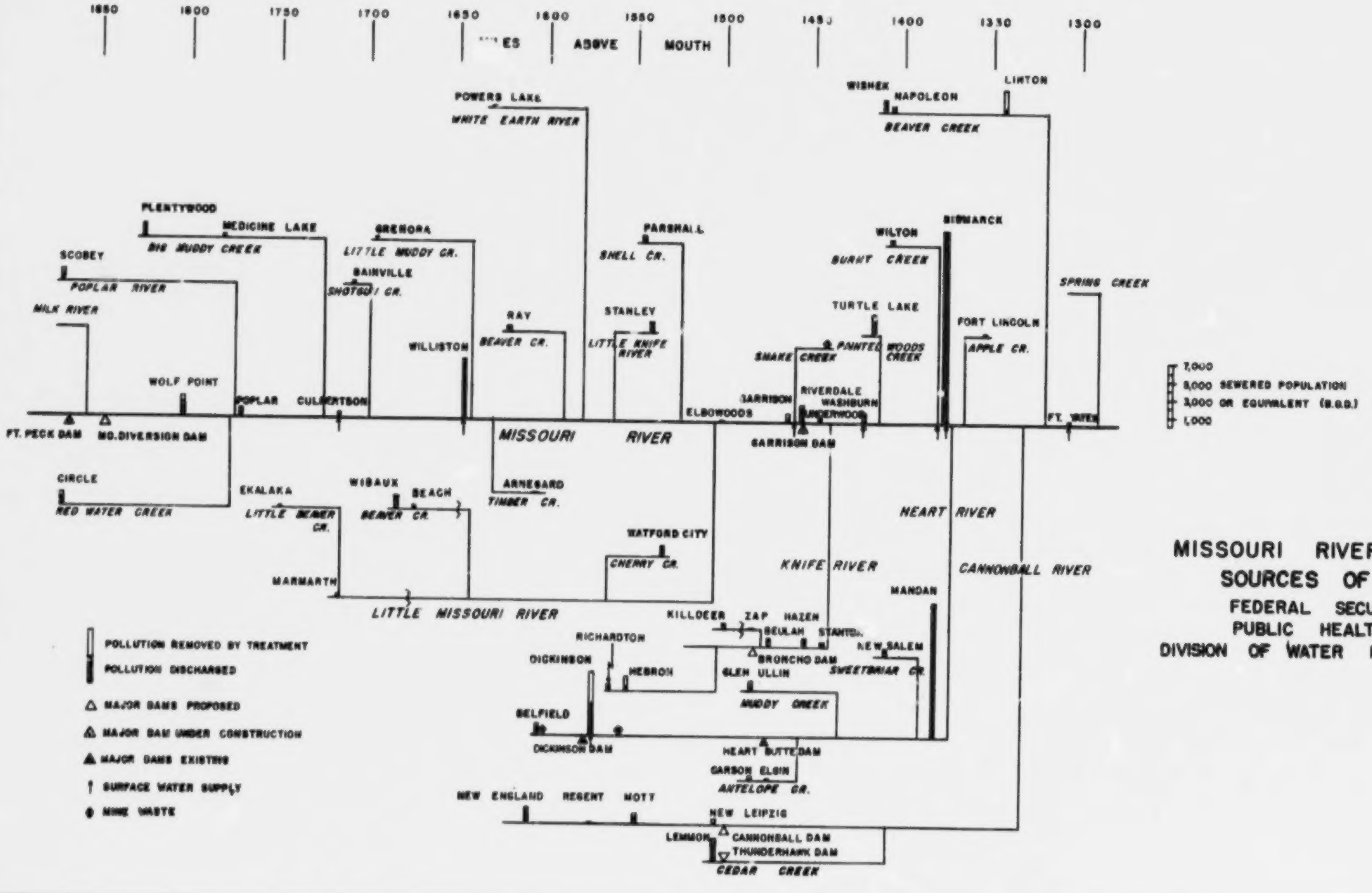
Table M-8. Missouri River Sub-Basin. Basic data on sources of industrial pollution - Industries discharging wastes directly to watercourse

Stream and industry	Miles above mouth		Type of industry	Type of waste produced	Population equivalent (B.O.D.) untreated waste	Treatment or other pollution control measure			Population equivalent discharged to watercourse	Pollution abatement needs or equiv. control measures	Current status industrial action
	Missouri River	Tributary				degree	Adequacy Cap'y	Adequacy Oper.			
Missouri River											
Ryder Co-op Creamery Ryder, N.D.	No defined drainage		Food products	Organic	880	Minor[a]	Sat.	Sat.	(800)[b]	None	-
Snake Creek	1460.0										
Custer Coal Mine Near Garrison, N.D.		15.0	Lignite mining	Mine drainage	Not applicable	None	-	-	e	None	-
Knife River	1440.6										
Spring Creek		38.6									
Bosch Meat Co. Halliday, N.D.		44.5	Food products	Organic	220	Minor[a]	Sat.	Sat.	None[c]	None	-
Bismarck Abattoir Bismarck, N.D.	1377.4		Food products	Organic	780	None	-	-	780	New plant	Inactive
Heart River	1373.3										
Andy's Coal Mine Belfield, N.D.		233.0	Lignite mining	Mine drainage	Not applicable	None	-	-	Not applicable	New plant	Inactive
Queen City Packing Co. Dickinson, N.D.		200.5	Food products	Organic	1,700	None	-	-	1,700	New plant	Inactive
Dakota Briquette & Tar Prod.Co. Dickinson, N.D.		186.0	Coal products	Inorganic	Not applicable	Lagoon	Sat.	Sat.	Not applicable	None	-
Dickinson Coal Mine Co. Dickinson, N.D.		184.0	Lignite mining	Mine drainage	Not applicable	None	-	-	Not applicable	New plant	Inactive
Armour & Co. Sunnyside, N.D.		13.7	Food products	Organic	160	None	-	-	None[d]	None	-
Mandan Livestock Sales Mandan, N.D.		8.0	Food products	Organic	120	None	-	-	None[d]	None	-
Miller & Swanick Mandan, N.D.		8.0	Food products	Organic	400	Minor[a]	Sat.	Sat.	None[c]	None	-
Russell Miller Milling Mandan, N.D.		8.0	Food products	Organic	360	None	-	-	360	Connected to municipal system	Inactive
Apple Creek	1365.1										
Northern Hide & Fur Co. Bismarck, N.D.		6.0	Food products	Organic	340	(c)	Sat.	Sat.	None[d]	None	-
Beaver Creek	1320.5										
Linton Slaughtering Linton, N.D.		31.0	Food products	Organic	250	None	-	-	250	New plant	Inactive
Total					5,210				3,890 (800)[f]		

---

[a] Septic tank.
[b] To local lake.
[c] Subsurface disposal.
[d] Waste does not reach watercourse.
[e] Discharge to intermittent creek - pollution reaches watercourse only during periods of high water.
[f] Wastes generally not reaching flowing watercourses.

FIGURE MI


1850
1800
1750
1700
1650
1600
1550
1500
1450
1400
1350
1300
ES ABOVE MOUTH
SCOBEY
POPLAR RIVER
MILK RIVER
PLENTYWOOD
BIG MUDDY CREEK
MEDICINE LAKE
GRENORA
LITTLE MUDDY CR.
BAINVILLE
SHOTGUN CR.
WOLF POINT
POPLAR
CULBERTSON
WILLISTON
RAY
BEAVER CR.
POWERS LAKE
WHITE EARTH RIVER
STANLEY
LITTLE KNIFE RIVER
PARSHALL
SHELL CR.
ELBOWOODS
GARRISON
SNAKE CREEK
PAINTED WOODS CREEK
TURTLE LAKE
RIVERDALE
WASHBURN
UNDERWOOD
GARRISON DAM
WILTON
BURNT CREEK
BISMARCK
FORT LINCOLN
APPLE CR.
WISHEK
NAPOLEON
LINTON
BEAVER CREEK
SPRING CREEK
FT. YATES
FT. PECK DAM
MO. DIVERSION DAM
MISSOURI RIVER
CIRCLE
RED WATER CREEK
EKALAKA
LITTLE BEAVER CR.
WIBAUX
BEACH
BEAVER CR.
MARMARTH
ARNEGARD
TIMBER CR.
WATFORD CITY
CHERRY CR.
LITTLE MISSOURI RIVER
KNIFE RIVER
HEART RIVER
CANNONBALL RIVER
KILLDEER
ZAP
HAZEN
BEULAH
STANTON
BRONCHO DAM
NEW SALEM
SWEETBRIAR CR.
MANDAN
RICHARDTON
HEBRON
DICKINSON
GLEN ULLIN
MUDDY CREEK
BELFIELD
DICKINSON DAM
HEART BUTTE DAM
CARSON
ELGIN
ANTELOPE CR.
NEW ENGLAND
REGENT
MOTT
NEW LEIPZIG
LEMMON
CANNONBALL DAM
THUNDERHAWK DAM
CEDAR CREEK
POLLUTION REMOVED BY TREATMENT
POLLUTION DISCHARGED
MAJOR DAMS PROPOSED
MAJOR DAM UNDER CONSTRUCTION
MAJOR DAMS EXISTING
SURFACE WATER SUPPLY
MINE WASTE
7,000
5,000 SEWERED POPULATION
3,000 OR EQUIVALENT (B.O.D.)
1,000

MISSOURI RIVER SUB-BASIN
SOURCES OF POLLUTION
FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
DIVISION OF WATER POLLUTION CONTROL

98-A

Table M-9. **Missouri River Sub-Basin** - **Probable frequency of low mean monthly flows**

Years of Record[1]	Stream and location	Drainage* area square miles	Low mean monthly discharge in c.f.s. that may be expected once in: 2 yrs.	3 yrs.	5 yrs.	10 yrs.	Low mean monthly flow of record
		SUMMER (JUNE-SEPT)					
15	Redwater Creek at Circle, Mont.	542	0.0	0.0	0.0	0.0	0.0
12	Middle Fork Poplar River at International Boundary	381	0.2	0.2	0.1	0.0	0.0
10	Poplar River near Bredette, Mont.	2,840	13	5.9	2.4	1.0	0.8
12	East Fork Poplar River at International Boundary	256	2.7	2.2	1.6	0.7	0.6
12	West Fork Poplar River at International Boundary	141	0.0	0.0	0.0	0.0	0.0
9	West Fork Poplar River near Richland, Mont.	-	0.4	0.2	0.2	0.1	0.1
12	Little Missouri River near Alzada, Mont.	640	0.8	0.2	0.0	0.0	0.0
10	Little Missouri River at Marmarth, North Dakota	-	42	31	18	11	7.0
6	Little Missouri River at Medora, North Dakota	6,323	32	12	0.6	0.3	0.3
9	Little Missouri River near Watford City, N.D.	8,490	126	84	58	22	1.4
10	Little Beaver Creek near Marmarth, N.D.	-	1.7	0.2	0.0	0.0	0.0
8	Beaver Creek near Wibaux, Mont.	311	0.7	0.1	0.0	0.0	0.0
6	Knife River near Golden Valley, N.D.	1,230	9.1	7.8	6.1	4.3	4.0
10	Knife River at Hazen, N.D.	2,352	26	22	17	12	7.6
5	Heart River at Lehigh, N.D.	453	2.8	2.5	2.1	1.8	1.8
6	Heart River near Richardton, N.D.	1,312	10	6.6	2.5	0.8	0.49
5	Heart River near Glen Ullin, N.D.	1,760	14	13	8.2	3.4	3.4
10	Heart River near Mandan, N.D.	3.362	31	23	8.9	5.1	2.3
5	Cannonball River near New Leipzig, N.D.	1,260	4.3	3.6	3.2	2.8	2.8
9	Cannonball River at Breien, N.D.	4,066	13	8.4	7.2	2.8	0.2
5	Cedar Creek near Pretty Rock, N.D.	1,260	0.5	0.5	0.3	0.1	0.1
52	Missouri River at Williston, N.D.	164,530	13,440	11,760	9.720	7,310	4,650
		WINTER (DEC-FEB)					
11	Redwater Creek at Circle, Mont.	542	0.0	0.0	0.0	0.0	0.0
11	Little Missouri River near Alzada, Mont.	640	0.2	0.1	0.0	0.0	0.0
9	Little Missouri River at Marmarth, N.D.	-	0.2	0.0	0.0	0.0	0.0
4	Little Missouri River at Medora, N.D.	6,323	4.3	2.1	1.3	0.7	0.8
9	Little Missouri River near Watford City, N.D.	8,490	0.2	0.0	0.0	0.0	0.0
9	Little Beaver Creek near Marmarth, N.D.	-	0.1	0.0	0.0	0.0	0.0
8	Beaver Creek near Wibaux, Mont.	311	0.3	0.2	0.2	0.1	0.0
5	Knife River near Golden Valley, N.D.	1,230	5.1	5.0	4.2	3.5	3.49
9	Knife River at Hazen, N.D.	2,352	11	7.6	6.7	6.3	6.0
4	Heart River at Lehigh, N.D.	453	2.4	1.3	0.9	0.6	0.72
5	Heart River near Richardton, N.D.	1,312	4.8	3.4	3	0.3	3
4	Heart River near Glen Ullin, N.D.	1,760	7.9	5.6	3.9	2.6	2.92
10	Heart River near Mandan, N.D.	3.362	3.6	1.4	0.4	0.0	0.0
4	Cannonball River near New Leipzig, N.D.	1,260	3.3	1.7	1.4	1.1	1.17
9	Cannonball River at Breien, N.D.	4,066	2.6	0.7	0.2	0.0	0.0
4	Cedar Creek near Pretty Rock, N.D.	1,260	1.4	1.0	0.8	0.7	0.75
52	Missouri River at Williston, N.D.	164,530	8,500	8,120	5.960	5.080	3,040

[1] Based upon U.S.G.S. records.

*From Corps of Engineers - revised 1949

reduced or had ceased altogether. These oxygen values are presented in table M-10. During the 1938-39 sampling period flow in the Missouri River remained above 5,000 c.f.s. During ice cover, oxygen decreased to 9.8 ppm. (67 percent of saturation). Although there are no dams in the river to provide reaeration, considerable portions of the stream remain open during subzero weather, and water currents keep the stream bed relatively free of organic accumulations.

DISCUSSION

The Missouri River Sub-Basin is an area of great contrasts: warm summers and cold winters; thunderous floods spaced within long periods of drought; constant flow in the Missouri and intermittent discharges from tributaries.

The Missouri River is used for water supplies, waste disposal, ice harvesting, irrigation, hydroelectric power, recreation, and fish and wildlife conservation. The development of the river's water resources has and will have increasing impact upon the economy and welfare of the region and of the entire nation.

Municipal Water Supplies

Ground water sources serve a population approximately equal to that securing water from surface supplies. Surface supplies serve 42,700 people with 4.045 million gallons per day while ground water is used by 36,370 consuming 2.720 million gallons per day.

Surface waters are of acceptable quality although hardness is somewhat excessive. Of eight surface supplies, one receives chlorination and settling, seven are treated by coagulation and filtration, and five of the latter also are softened.

The harvesting of ice from streams of the Basin for public use adds importance to stream pollution as ice has been known to carry disease organisms. Ice should be secured from waters of satisfactory quality and handled and stored properly to preclude contamination.

Ground waters in this region are generally quite highly mineralized and seldom yield an adequate quantity. Possibly 75 percent of ground water sources are deficient in either quality or quantity.

Apparently the solution to existing water problems lies in more effective use of surface water sources, although the practice will require treatment works to assure a safe and potable supply. Pollution control will be of additional import as municipalities resort more and more to streams for their water supplies.

The water resource development program will aid many communities in their water problems. Diversion canals may supply some cities directly, irrigation canals may be utilized by others. Dispersion of waters over land by irrigation practices will tend to raise ground water levels. The Bureau of Reclamation indicates that communities

Table M-10. Missouri River Sub-Basin - Dissolved oxygen at Bismarck, North Dakota[1]

Date	Station[2]	Temperature °C	pH	Dissolved oxygen ppm.	Dissolved oxygen Percent saturation	Remarks
Nov. 7, 1938	River	2	8.2	12.9	93.2	
Nov. 7, 1938	Plant	2	-	12.8	92.5	
Nov. 16, 1938	River	0	-	12.7	86.8	
Nov. 16, 1938	Plant	0	-	12.7	86.8	Ice floating in river.
Nov. 22, 1938	River	0	-	12.6	86.2	
Nov. 22, 1938	Plant	0	-	12.6	86.2	Ice floating in river.
Nov. 28, 1938	Plant	0	8.1	13.1	89.5	Ice cover for 4-5 days.
Dec. 6, 1938	Plant	0	8.1	12.9	88.2	River ice covered.
Dec. 13, 1938	Plant	0	8.1	12.7	86.8	
Dec. 20, 1938	River	0	8.1	12.8	87.5	Hole in ice - 13.5' water.
Dec. 30, 1938	Plant	0	8.1	12.9	88.2	
Jan. 12, 1939	River	0	-	11.7	80.0	600' above R.R. bridge - ice harvesting.
Jan. 12, 1939	Plant	0	8.1	11.7	80.0	10' water. Few small open stretches.
Jan. 16, 1939	River	0	8.0	11.7	80.0	600' above R.R. bridge - 20" ice, 6' water.
Jan. 16, 1939	Plant	0	-	11.7	80.0	
Feb. 11, 1939	Plant	0	8.0	10.8	73.9	
Feb. 18, 1939	Plant	0	8.0	10.3	70.5	
Feb. 25, 1939	Plant	0	7.9	9.8	67.0	
Mar. 6, 1939	Plant	0	8.0	10.9	74.5	
Mar. 17, 1939	Plant	0	8.0	10.8	73.9	
Apr. 6, 1939	Plant	3.5	7.9	11.2	84.0	
Apr. 22, 1939	River	10	-	11.3	99.6	
May 5, 1939	River	17	-	8.4	86.3	
May 31, 1939	Plant	18.5	-	7.65	81.0	
June 15, 1939	River	17	-	8.13	83.5	
June 15, 1939	Plant	17	-	8.18	84.0	

---

[1] Information from Red River of the North Research Investigation issued by North Dakota State Department of Health.

[2] Station: River-sample taken directly from river above Bismarck.
Plant-sample taken at inlet well, Bismarck water treatment plant.

listed in table M-11 may derive water supply benefits from existing or proposed impoundments and diversion. In addition, private water supplies may also be improved. However, benefits may only be realized where flow routing and location of the municipality permit improvement over existing water supplies.

Ground waters infiltrated by irrigation seepage should be analyzed for nitrate content prior to usage for domestic consumption. The relationship between water supplies with relatively high nitrate nitrogen and a malady of infants (methemoglobinemia) is becoming more clear and indicates its public health importance. Tentative standards stating that potable water should not contain more than 10 ppm. nitrate nitrogen have been established by some State Health Departments. A detailed discussion of this subject is presented in appendix D.

Table M-11. Missouri River Sub-Basin - Communities which may derive water supply benefits by existing and proposed impoundments and diversions[1]

- MISSOURI RIVER VALLEY
  - Montana
    - Antelope
    - Bainville
    - Brockton
    - Culbertson
    - Frazer
    - Froid
    - Homestead
    - Medicine Lake
    - Poplar
    - Reserve
    - Wolf Point
  - North Dakota
    - Bismarck
    - Coleharbor
    - Fort Yates
    - Garrison
    - Linton
    - Mercer
    - Parshall
    - Sanish
    - Trenton
    - Turtle Lake
    - Underwood
    - Van Hook
    - Washburn
    - Williston
- LITTLE MISSOURI RIVER VALLEY
  - North Dakota
    - Marmarth
    - Medora
- KNIFE RIVER VALLEY
  - North Dakota
    - Beulah
    - Dodge
    - Dunn Center
    - Golden Valley
    - Halliday
    - Hazen
    - Killdeer
    - Stanton
    - Zap
- HEART RIVER VALLEY
  - North Dakota
    - Dickinson
    - Gladstone
    - Mandan
- CANNONBALL RIVER VALLEY
  - North Dakota
    - Elgin
    - Mott
    - New Leipzig
    - Shields
    - Solen

---

[1] From Bureau of Reclamation.

Industrial Water Supplies

Twenty industrial establishments that utilize ground water for part or all of their supply are listed in table M-6. Average daily consumption totals 0.628 M.G.D. Industrial water use is quite limited.

Irrigation Water

The public health significance of pathogenic contamination in irrigation waters is of considerable import. Caution must be exercised in the use of irrigation waters containing high bacterial counts on low growing vegetables likely to be consumed raw, particularly if the contamination is of very recent origin. A review of public health aspects of irrigation with sewage polluted waters is given in appendix C.

Sources of Pollution and Status of Sewage Treatment

Of the 57 communities listed in table M-12, 9 discharge untreated sewage and 10 provide only minor treatment, usually a septic tank which, for municipal sewage, may be considered effecting little or no treatment. Thirty-two of the remaining 38 municipalities provide primary and 6 provide secondary treatment before discharge of their sewage. One town, Grenora, North Dakota, included in those providing secondary treatment, disposes of its sewage satisfactorily in a lagoon.

Table M-12. Missouri River Sub-Basin - Existing municipal* sewage treatment facilities

Degree of treatment provided	Number		Population served
	Municipalities	Plants	
Minor[a]	10	10	11,300
Primary	32[b]	32	20,080
Secondary	6	6	10,520
No treatment	9	-	38,650

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

[a] Septic tank.

[b] Includes one new system under construction.

The adequacy of existing treatment facilities with relation to operation and design capacity is given in table M-13. Of 47 existing municipal treatment works shown in this table, the capacity of 12 and the operation of 13 are unsatisfactory.

Table M-13. Missouri River Sub-Basin - Adequacy of existing waste treatment facilities

Existing treatment facilities	Number	Adequacy with relation to: Capacity		Adequacy with relation to: Operation	
		Satisf.	Unsatisf.	Satisf.	Unsatisf.
Municipal*	47	35	12	34	13
Industrial**	5	5	0	5	0

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

** Industries having separate outlets discharging wastes directly to watercourse.

Table M-8 indicates 14 sources of industrial pollution. Four establishments, a coal processor and three lignite strip mines produce inorganic waste; ten food processors have organic wastes. The coal processing plant provides adequate treatment by lagooning its waste. One of the three mines discharges satisfactorily to the bed of an intermittent creek, and the other two discharge to the Heart River with no treatment. Of the ten food product industries, six discharge waste without treatment and four have sufficient minor treatment. As shown in table M-13, all five (four food processors and one mine) of the industries providing waste treatment have satisfactory capacity and operation.

Recent discoveries of oil in eastern Montana and western North Dakota may introduce a new type of waste to the area. The limited amounts of oil thus far brought in have not created pollution problems of any importance.

Stream Conditions

Missouri River

This section of the Missouri has a drifting channel with caving banks and numerous cut-offs. Shifting of the channel results in formation of numerous bayous, oxbows, and marshy areas. Above Fort Rice, North Dakota, the river valley is several miles wide, but is pretty well confined in a narrow valley below Fort Rice, where it develops only occasional large bends. The river is fairly wide in this narrow valley, and is sometimes divided into two or more channels by sandbars or permanent islands. Timber is usually quite dense between bluff lines.

Usually two "rises" of river stage occur each year, one in March and one in June. The earlier high stage comes from melting of snow throughout the upper Basin, while the second high stage occurs as a result of rainfall coupled with melting of snow and ice on mountains near the headwaters.

It seems reasonable to assume that the stretch of the Missouri from Fort Peck Dam to the mouth of the Yellowstone is considerably less turbid than anywhere below the Yellowstone, but little is known concerning the physical, chemical, and biological features of this part of the river.

Plankton samples collected during the summer of 1950 indicate a predominance of diatoms among the phytoplankters (or plant plankters) and disclose densities ranging from 70,000 to 1,200,000 organisms per liter. Such concentrations show that turbidity of this stretch of the river, while no doubt suppressing plankton to some extent, is not sufficient to interfere markedly with development of these organisms.

Despite the apparent unfavorable aspects of high turbidity, shifting bottom, and drifting channel, this section of the Missouri supports a relatively high fish population. Commercial fishing on the river is restricted by the shifting nature of bottoms and channels that makes both navigation hazardous. Commercial fishing is a part time occupation of few people, all fish are sold to local markets. The channel catfish is one of the most abundant as well as the most important food species. Other fishes present are carp, skipjack, flathead chub, sauger, bullhead, sturgeon, sucker, paddlefish, burbot, and walleye. Lack of commercial fishing pressure may be partly responsible for the relatively high fish population.

The Fish and Wildlife Service[1] reports that fishing has been substantially improved down to the region of Wolf Point, Montana, by construction of Fort Peck Dam. It seems likely that better conditions for fishes arise from lessened turbidity and more uniform discharge, although increased productivity of the river could be the result of releases of bottom water from the reservoir. Thermal records made during the summer of 1950 show Fort Peck Reservoir to be stratified. Discharge tunnels to the right of the dam and to the power house release water devoid of oxygen from a considerable distance below the surface of the lake. Reaeration of oxygen deficient water could be expected to produce nitrates and phosphates in the river with attendant increase in either plankton or bentheric algal growh, probably the latter. Discharges over the spillway would be from surface water of the lake and could not be expected to have a marked positive effect upon productivity of the river below. Both surface and bottom waters discharged from the lake would be expected to have a lower mineral concentration than water entering the reservoir, as a result of dilution and biological action.

Little Missouri River

Information concerning aquatic life in this river and its tributaries is scanty. The Fish and Wildlife Service[2] reports that channel catfish are present all along the river, and that suckers and carp probably occur. The chemical constitution of water (table 2-A General Section) appears favorable for high biological productivity, but high turbidity and the unstable character of the bottom would appear to militate against the potential offered by various materials in solution. Plankton samples taken during summer of 1950 indicate the deceptive nature of the outward appearance of this river. For instance, densities up to 24,000,000 organisms per liter occurred at a station on the river located due south of Williston, North Dakota, while concentrations of 540,000 per liter were found in the river near Alzada, Montana. Dominant organisms at the former location were Cyclotella, Synedra, and Actinastrum, and at Alzada, diatoms and flagellates. It is suspected that the presence of Cyclotella and Synedra is the result of benthic or bottom growth, although no definite information bearing on this point is available. Plankton concentrations do indicate a high productive capacity of the water.

---

[1] A Preliminary Report on Fish and Wildlife Resources in Relation to the Proposed Plan for Erosion Control and Navigation on the Missouri River in Montana, North Dakota, South Dakota, and Nebraska, 1948.

[2] A Preliminary Report on Fish and Wildlife Resources in Relation to the Water Development Plan for the Little Missouri River Basin: 1951.

During conditions of ice cover the shallow pools probably induce much winter kill among fishes that remain in the Little Missouri. It is not unlikely that some migration to the Missouri River occurs in late fall.

Plans of the Bureau of Reclamation envision the construction of a dam on the Little Missouri, although no definite site has been selected. If the dam is constructed at some distance from the headwaters at Marmarth, North Dakota, or below, the quality of the water should be definitely improved. Inasmuch as a portion of the silt in suspension appears to be colloidal in size, clarification of the water in a reservoir would likely be incomplete, although settling of colloidal particles would be expedited by development of a phytoplankton population in the reservoir. Because of the presence of nutrients and clear waters, it seems that a dense plankton population in the reservoir is assured. The stream below the reservoir would carry much less silt and hardness would be reduced. Construction of a stilling basin below the dam would be highly desirable.

Knife River

Flow in the Knife is erratic and highly variable. Largest flows usually occur during the spring thaw, and are generally of short duration, since snow melts in all parts of the Basin at practically the same time. Floods due to heavy rains sometimes occur in June or July, and low stages prevail during late summer and winter months.

Bank erosion and bed scour are of minor importance, but the river has developed a meandering course that has left many small oxbow sloughs scattered along its length. Most sloughs are filled with water each spring, but all become dry in early summer, and little marsh area is present. The river channel averages 15 feet deep and 40 feet wide, and has high cut banks in many localities. Banks are generally covered with broad leaf trees and shrubs.

The river bottom is composed of sand and silt, but silt content of the water is much lower than that of the Little Missouri. The river is comparatively clear except during flood stages. Concentration of various minerals, particularly sodium salts, is high at low water stages, but water quality is satisfactory to support species of fish present in this part of the Missouri Basin. Knife River fishes in their order of abundance are: carp, suckers, goldeye, channel catfish, bullheads, and walleye. The large numbers of carp are considered detrimental to the fishery, and channel catfish and walleyes would seemingly be the most desirable species. Bullheads form a substantial portion of the annual hook-and-line catch. The river is a poor fishing stream.

There is a general lack of information concerning aquatic life other than fishes, and it may only be assumed that development of aquatic organisms proceeds on similar lines to that of the Little Missouri, although lesser turbidity and more stable bottom would appear to provide more favorable conditions for both photosynthetic organisms and benthic animals. The only unfavorable chemical element would appear to be the high sodium content. Construction of Broncho Reservoir should reduce mineral content and furnish better quality water to the stream below.

Cannonball River

The Cannonball has a narrow valley near its headwaters, where the slope is steep, but gradually levels off and meanders through a valley approximately two miles wide in its lower reaches. In upper regions the channel is bordered by high steep banks. Flow in the river is very erratic (0 to 94,800 second-feet) and the average annual flow amounts to about 277 second-feet. Zero flows for protracted periods have occurred during January and February. High flows usually come during March and April and again in June and July. The river carries considerable silt during periods of high flow, but is clear the rest of the year.

One plankton sample taken due south of Bismarck in summer, 1950, showed a density of 4,640,000 organisms (mostly the diatoms, Synedra, and Navicula) per liter, and indicates a high productive capacity of the stream. This, however, does not appear unusual for streams in the general area. The Fish and Wildlife Service[1] predicts that increased fishery values will accrue to potential Cannonball Reservoir, although no great value may be assigned to the fishery at present. Wide fluctuations in flow coupled with winter kill under ice cover appear to militate strongly against the establishment of a worth-while fishery under present conditions. Species occurring in the Cannonball River are yellow pike perch (walleye), channel catfish, bullheads, yellow perch, crappie, carp, and suckers. Best fishing in the river is in the potential reservoir area.

Heart River

Heart River stream conditions may not be closely approximated from available data. It may be assumed that limnological aspects resemble those of the Knife River, although allowance should be made for mine drainage, which may have marked effects.

---

[1] A Preliminary Evaluation Report on Fish and Wildlife Resources in Relation to the Water Development Plan for the Cannonball Unit, 1951.

Table M-14. Missouri River Sub-Basin - Project list

Name	Population equivalent	Treatment: Existing	Treatment: Needs (or equivalent industrial waste control measures)	Project
MONTANA				
Wolf Point	2,400	Minor[a]	Primary	New plant
Scobey	1,450	Minor[a]	Secondary	New plant
Plentywood	1,600	None	Secondary	New plant
Medicine Lake	350	Minor[a]	Primary	New plant
Wibaux	500	Minor[a]	Primary	New plant
NORTH DAKOTA				
Williston	6,810	None	Primary	New plant
Stanley	1,320	Primary	Secondary	Addition
Marmarth	400	Minor[a]	Primary	New plant
Beach	1,100	Minor[a]	Secondary	New plant
Riverdale	2,000	None	Primary	New plant
Beulah	1,000	Minor[a]	Primary	New plant
Stanton	500	None	Primary	New plant
Washburn	1,200	None	Primary	New plant
Bismarck	21,700	None	Primary	New plant
Bismarck Abattoir	780	None	Primary	New plant
Belfield				
Andy's Coal Mine	Not applicable	None	-	New plant
Dickinson	7,050	Secondary	Add'l.treatment	Addition
Queen City Packing Company	1,700	None	Secondary	New plant
Dickinson Coal Mine Company	Not applicable	None	-	New plant
North Dakota State Training School	550	None	Primary	New plant
Mandan	15,000	None	Secondary	New plant
Russell Miller Milling	360	None	Primary	Connect to municipal system
Fort Lincoln	200	None	Secondary	New plant
New England	1,740	Minor[a]	Secondary	New plant
Mott	1,260	Minor[a]	Secondary	New plant
Linton				
Linton Slaughtering	250	None	Primary	New plant
SOUTH DAKOTA				
Lemmon	2,300	Minor[a]	Secondary	New plant

[a] Septic tank.

Sewage and Waste Treatment Needs

Recommendations for the degree of waste treatment needed by municipalities and industries appearing in table M-14 were arrived at by observing conditions during the present pollution investigation and by analysis of historical stream discharge records. The recommendations do not consider the possibility of an increase or reduction in minimum flows which may result from the proposed water resource management program. This subject will be discussed in a later section.

Requirements for municipal and industrial waste treatment plants (table M-15) indicate that new plants are required by 19 municipal sewer systems serving 49,950 people. Two systems serving 7,200 people require enlargement or addition to the existing plants, and 35 systems serving 22,950 people adequately dispose of their wastes. Six industries require new waste treatment plants (one of which may connect to municipal sewerage) and eight have no needs. Table M-16 shows that no formal action has been taken by 20 municipalities and 6 industries, while 1 municipality has had its final plans approved and 1 new system is under construction.

Table M-15. Missouri River Sub-Basin - Municipal and industrial waste treatment needs

Needs	Municipal* Number	Municipal* Population served by facilities	Industrial** Number
New plant	19	49,950	6[a]
Enlargements or additions to existing plant	2	7,200	0
Replace existing plant	0	0	0
No project required	35	22,950	8

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets discharging wastes directly to watercourse.

[a] An alternate solution for one plant would entail connection to municipal sewerage.

Table M-16. Missouri River Sub-Basin - Status of municipal* and industrial** action on pollution abatement needs

Status of project	Number Municipal	Industrial
No formal action	20	6
Abatement ordered	0	0
Plans under preparation	0	0
Final plans approved	1	0
Construction awaits financing	0	0
Under construction	1[a]	0

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets discharging wastes directly to watercourse.

[a] New system.

Of the 27 sewage treatment projects required, secondary treatment facilities are needed at Scobey and Plentywood, Montana; Beach, Mandan, Fort Lincoln, New England, and Mott, North Dakota; and Lemmon, South Dakota. Stanley, North Dakota, should install additional secondary treatment facilities to complement the existing primary plant, and Dickinson, North Dakota, should provide additional capacity for the existing secondary treatment plant. Primary treatment facilities should be provided by the following municipalities: Wolf Point, Medicine Lake, and Wibaux, Montana; and Williston, Marmarth, Riverdale, Beulah, Stanton, Washburn, Bismarck, and State Training School, North Dakota.

Industries in the Sub-Basin requiring waste treatment are: Queen City Packing Company at Dickinson - secondary treatment or equivalent control measures; the Bismarck Abattoir, Russel Miller Milling Company at Mandan, and the Linton Slaughterhouse - primary treatment or equivalent control measures. The mill at Mandan may best connect to municipal sewerage. Mine drainage from Andy's Coal Mine at Belfield, and Dickinson Coal Mine should be controlled to prevent harmful effect on downstream water users.

It has been estimated that construction costs for new facilities and improvements may approximate $2,750,000.

Table M-17 shows that in the years following the close of World War II municipal sewerage plant construction reached peaks in 1948 and 1950 with the installation of five plants during each of these years. Two plants were installed during each of the two years 1946 and 1951, three plants during 1947, and none during 1949. No industrial waste treatment plants were constructed during these six postwar years.

Table M-17. Missouri River Sub-Basin - Progress in pollution abatement

	Municipal*		Industrial**	
Year	Plants completed	Design population	Plants completed	Amount of waste treated
1946	2	2,500	0	-
1947	3	4,800	0	-
1948	5	4,400	0	-
1949	0	-	0	-
1950	5	3,375	0	-
1951	2	1,800	0	-

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets discharging wastes directly to watercourse.

Flow Needs Evaluation

The development program may alter appreciably existing low flow patterns in streams. Increased minimum flows may permit benefits in the form of a lower degree of sewage treatment being necessary, improved water quality and increased water volume for municipal and industrial uses, and enhanced fish and wildlife propagation. On the other hand, damages may occur to these uses if stream flows are reduced below the required minimum, provided normal flows are equal to or above minimum needs. Regulation which provides minimum flows equal to unregulated minimums naturally prevailing would create worse stream conditions during the time natural stream flows would have exceeded the regulated minimums.

In evaluating flow needs in this Sub-Basin, it has been assumed that flow in the stretch of the Missouri River under consideration would be maintained well above the minimums required. Sources of pollution in this area are not great and are generally separated by considerable distances. Bismarck, North Dakota, is the largest source of pollution. On tributary streams Broncho Dam on the Knife River, and Dickinson and Heart Butte Dams on the Heart River, may affect downstream municipal uses. It is not possible in this report to include all the detailed phases of numerous pollution problems. Certain instances will require more study while large increases in populations, new industry, or expansion of existing industry will call for revision of specified flows or sewage treatment needs. Future improvements in the science of sewage treatment will also have its impact.

Flows specified in table M-18 are those required to assimilate residual oxygen-consuming matter remaining after a designated degree of waste treatment has been provided without lowering the oxygen

Table M-18. Missouri River Sub-Basin - Flow needs at given locations and cost evaluations

Municipality (1)	Stream (2)	River mile location (3)	Minimum normal flow[1] c.f.s. (4)	Primary (35%) treatment minimum flows[1] c.f.s. (5)	Secondary (75%) treatment minimum flows[1] c.f.s. (6)	Annual tangible monetary benefits possible if flow in column 5 provided (7)	Annual tangible monetary benefits possible if flow in column 6 provided (8)
Beulah, N.D.	Knife R.	32	-	5	2	0[b]	0[b]
Hazen, N.D.	Knife h.	12.5	12	5	2	0[b]	0[b]
Stanton, N.D.	Knife R.	0.5	-	5	2	0[b]	0[b]
Dickinson, N.D.	Heart R.	201.3	2[a]	23	9	$ 18,630	$ 6,210
Mandan, N.D.	Heart R.	7	9	45	18	24,830	8,280
TOTAL						$ 43,460	$ 14,490

[1] Summer flows.
[a] Estimated.
[b] Damages are possible if flows are reduced below 5 c.f.s.

content in the stream below that required for balanced aquatic life--5 ppm. Treatment levels considered have included primary treatment--35 percent B.O.D. removal, secondary treatment--75 percent B.O.D. removal, and an exceptionally high degree of secondary treatment or a tertiary process--85 percent B.O.D. removal.

The desirable flows will provide a basis for comparing cost of additional treatment against the value of water for other uses. Included in the table are tangible annual monetary benefits that would result from savings in pollution control by lower degrees of required sewage treatment based upon these desirable flows.

In the Knife River Basin benefits from maintenance of desirable flows are not possible as the normal minimum flow--that minimum average monthly flow expected to occur once in ten years--is greater than the needs after primary treatment of sewage. However, should the water management program reduce flows below those required after primary treatment of sewage, damages are possible.

Two locations, Dickinson and Mandan, on the Heart River have been evaluated. It has been estimated that provision for minimum flows as indicated would provide benefits totaling $43,460 if flows high enough for primary treatment to suffice are provided and $14,490 if nominal secondary treatment is necessary. These values are not the only benefits afforded by increased stream discharges. Fish and wildlife conservation and recreation would be increased and there would be numerous intangible benefits.

Table M-19 gives the flow needs by months below Dickinson and Mandan. It will be observed that winter flow needs exceed those of the summer period because of ice cover considerations. Proper sewage treatment and disposal at Mandan will necessarily involve considerable study. Mandan, located only a short distance upstream from the confluence of the Heart and Missouri Rivers, may find it more economical to install a long outfall sewer and discharge its treated waste directly to the Missouri River. The advantage of such a method would be the possibility of installing only primary treatment with lower annual operation and maintenance charges, even though initial cost of the long outfall sewer may be quite high.

Table M-19 also shows future ultimate estimated flows to indicate probable dilution water needs for resource planning. It was assumed, as discussed in the General Section, that the present pollution load would double by 1980 and that present firm treatment efficiencies would improve by 10 percent. Meeting these flows in the future would increase benefits in the form of less costly treatment plant additions or replacements needed for future loads.

Table M-19. Missouri River Sub-Basin - Flow needs in c.f.s. by months for critical locations

	Dickinson				Mandan			
	Present		Future (1980)		Present		Future (1980)	
Month (1)	Primary 35% (2)	Secondary 75% (3)	Primary 45% (4)	Secondary 85% (5)	Primary 35% (6)	Secondary 75% (7)	Primary 45% (8)	Secondary 85% (9)
January	34	14	50	15	16	6	24	7
February	34	14	50	15	16	6	24	7
March	20	8	30	10	14	5	20	6
April	12	5	20	6	18	7	30	8
May	12	5	20	6	28	13	45	12
June	23	9	40	11	45	18	75	20
July	23	9	40	11	45	18	75	20
August	23	9	40	11	45	18	75	20
September	23	9	40	11	45	18	75	20
October	12	5	20	6	22	8	35	9
November	12	5	20	6	14	5	20	6
December	34	14	50	15	16	6	24	7

SOURIS RIVER SUB-BASIN

TABLE OF CONTENTS

	Page
Summary	117
Conclusions	118
Description	119
Water Resource Development	121
Existing Projects	121
Potential Development Projects	121
Presentation of Data	123
Municipal Water Supplies	123
Industrial Water Supplies	123
Pollution Contributed to Water Resources	125
Low Flow Frequencies	127
Laboratory Results	127
Discussion	131
Municipal Water Supplies	131
Industrial Water Supplies	132
Irrigation Water Quality	132
Sources of Pollution and Status of Sewage Treatment	133
Stream and Lake Conditions	134
Sewage and Waste Treatment Needs	137
Flow Needs Evaluation	140

LIST OF TABLES AND FIGURES

Table		Page
S-1	Principal tributaries and their drainage areas . . .	119
S-2	Population of municipalities	120
S-3	Development program dams	122
S-4	Municipal surface water supplies	123
S-5	Municipal ground water supplies	124
S-6	Industrial surface water supplies	125
S-7	Industrial ground water supplies	125
S-8	Basic data on sources of municipal pollution . . .	126
S-9	Basic data on sources of industrial pollution . . .	128
S-10	Probable frequency of low mean monthly flows . . .	129
S-11	Communities which may derive water supply benefits by existing and proposed impoundments and diversions .	132
S-12	Existing municipal sewage treatment facilities . . .	133
S-13	Adequacy of existing waste treatment facilities . .	133
S-14	Project list	138
S-15	Municipal and industrial waste treatment needs . . .	139
S-16	Status of municipal and industrial action on pollution abatement needs	139
S-17	Progress in pollution abatement	140
S-18	Flow needs at given locations and cost evaluation . .	141
S-19	Flow needs in c.f.s., by months for critical locations.	142

Figure		Page
S-1	Sources of Pollution and Stream Sampling Data (August 1950)	130
S-2	Sources of Pollution and Stream Sampling Data (January and February 1951)	130

SUMMARY

This section of the report is concerned with the United States portion of the Souris River watershed and the Devils Lake drainage area. The Souris River rises in Canada, crosses the International Boundary into North Dakota, and then finally loops back into Canada. Landlocked Devils Lake area lies east of the Souris. Both are included in the proposed Missouri River Basin Development Program.

Agriculture and its related activities are the principal means of a livelihood for the population. Although there are 92 communities in the region, only two cities, Minot and Devils Lake, have populations exceeding 5,000. Most communities have less than 500 inhabitants. The total population of the Sub-Basin is estimated at 123,800.

The lack of water supplies, either from surface or underground sources, has probably been the principal deterrent to greater development of the region. There is one public surface water supply--an Indian Agency--and 23 municipal ground water supplies. Minot is changing to a surface source, the Souris River. Many industries use municipal supplies, 12 have private well sources, and a sand and gravel company uses the Souris River. This river is also used for power plant cooling water.

U. S. Geological Survey data on stream discharge within the region indicate a general paucity of water with flows diminishing to zero almost every year. The quality of stream water is generally satisfactory for domestic purposes but somewhat harder than desirable. Stream characteristics indicate that fishing will be generally poor. Lakes in the Devils Lake area receded during the fifty years prior to 1941; since then the trend has been upward. As a result of the over-all reduction of water volume, mineral constituents have become so concentrated that the water is practically unuseable. Total solids vary from 7,000 to over 100,000 ppm. Fish have entirely disappeared from Devils and Stump Lakes.

The pollution contributed to watercourses from 19 municipalities and 11 industries is organically equivalent to that produced from 43,570 people. Drainage from three coal strip mines and washings from a sand and gravel plant produce inorganic wastes.

An oxygen depression in the Souris River was noticeable below the waterfowl refuges and below Minot. Bird droppings and weeds are considered accountable for the depression of the oxygen level in the waterfowl refuge impoundments; domestic and industrial wastes emanating from the City of Minot cause reduction of oxygen in the Souris River below that point. A new sewage treatment plant is being constructed at Minot.

Ten new municipal sewage treatment works, one replacement and four new industrial waste treatment works are considered necessary to prevent or abate pollution in the Souris Sub-Basin. Improvement in operation is needed at eight municipalities. The cost of constructing the new facilities and improvements is estimated at $2,785,000.

The proposed plan to divert water from the Missouri River to supplement supplies in the Souris-Devils Lake region will greatly enhance industrial and community growth. Annual benefits exceeding $53,000 are possible from the water regulatory program in the form of reduced waste treatment costs. Minimum recommended flows and benefits to be derived by each municipality are listed in table S-18.

Pollution abatement needs are based primarily upon the necessity for protecting domestic water supplies, both present and future, aquatic life, and irrigation. Under existing stream flow conditions, a high degree of secondary waste treatment is indicated. Treatment is practiced extensively and is being constantly improved under the guidance of the North Dakota State Department of Health.

CONCLUSIONS

1. Inadequate water supplies and poor water quality have hindered development of this region.

2. There is one public surface water supply and another under construction. The remaining communities utilize ground sources. Most industries having private water sources use wells.

3. Municipal and industrial waste are polluting river reaches below the larger cities and towns sufficiently to reduce stream oxygen content below levels necessary to support balanced aquatic life.

4. Treatment of all sewage wastes contributed to streams and lakes of the Sub-Basin is recognized by the North Dakota State Department of Health as essential to a successful pollution control program.

5. Ten new municipal waste treatment plants and one replacement are indicated. The installation of four new industrial waste treatment plants is considered necessary.

6. Municipal sewage and industrial wastes of the Souris Basin are composed primarily of organic materials, amenable to conventional treatment processes. A small portion of industrial waste is highly mineralized mine drainage which must be controlled by other means.

7. Organic pollution in the waterfowl refuges is sufficiently great to exert a substantial depressing effect on the oxygen content of the waters of the Des Lacs and Upper Souris River and may be responsible for the winter killing of fish.

8. The importation and conservation of water will be of considerable value to municipalities and industry for reducing waste treatment needs, and at the same time improving over-all water quality. The water resource development program is supplementary to adequate municipal sewage and industrial waste treatment.

9. Raising the level of Devils and Stump Lakes will not automatically insure conditions conducive to the development of a fish population. Desirable dilution of mineral content may be obtainable only by maintaining strict flow regulation.

10. The water management and flow regulation program should endeavor to provide wherever possible, the primary treatment minimum flow needs specified in tables S-18 and S-19.

DESCRIPTION

The Souris River Sub-Basin as designated in this report is that area in the United States draining to the Souris River, and the Devils Lake drainage area, a landlocked region (figure 1). The Souris River, tributary to the Red River, rises in Canada, flows southeasterly into the United States and finally bends back to re-enter Canada. The U. S. loop of the Souris drains an area of 8,862 square miles, all in North Dakota. Table S-1 lists the principal U. S. tributaries and their drainage areas.

Table S-1. Souris River Sub-Basin - Principal tributaries and their drainage areas

Stream	Miles upstream International Boundary	Drainage area square miles
Souris River		8,862
Des Lacs River	242.5	-
Wintering River	130.5	-
Willow Creek	57	-
Cut Bank Creek	28.2	-
Devils Lake Area	-*	3,940

*Landlocked

Populations of 92 communities in the Sub-Basin are presented in table S-2. Only two cities, Minot and Devils Lake, have populations exceeding 5,000. Most communities have less than 500 inhabitants. Analysis of census data indicates that larger cities have exhibited uniform growth, although all counties but one suffered population losses in recent years. The total population is approximated at 123,800.

Agriculture and related industries form the backbone of the region's economy. Chief contributors to farm incomes are livestock, wheat, corn, and potatoes. Most urban communities have food processing industries. Lignite coal is an important mineral asset. Following institution of the land and water resource development program, farm production should expand beyond present limits, accompanied by growths in related industries.

Climate is rigorous. Winters are generally long and severe; summers short and warm. Records indicate a temperature range from -46° F. to 112° F. Average annual rainfall is 17 inches.

Table S-2. Souris River Sub-Basin - Population of municipalities

Municipality	Population - U. S. Census			
	1920	1930	1940	1950
Souris River Valley				
North Dakota				
Ambrose	389	334	294	286
Antler	265	318	254	217
Balfour	322	197	193	162
Bantry	-	-	125	125
Barton	158	170	157	102
Belcourt	-	-	200	-
Benedict	195	145	167	127
Berthold	498	511	428	459
Bottineau	1,172	1,322	1,739	2,268
Bowbells	643	695	787	806
Burlington	-	-	300	-
Butte	252	231	261	272
Carpio	244	344	322	194
Columbus	332	516	506	525
Coteau	-	-	125	100
Crosby	1,147	1,271	1,404	1,689
Deering	142	192	140	136
Des Lacs	188	205	197	180
Donnybrook	267	259	215	207
Drake	517	644	654	831
Dunseith	374	484	719	713
Flaxton	374	423	362	436
Fortuna	198	196	214	181
Foxholm	-	-	250	-
Gardena	99	120	125	116
Glenburn	228	263	190	281
Granville	394	450	443	404
Guthrie	-	-	100	-
Karlsruhe	-	258	289	282
Kenmare	1,446	1,494	1,528	1,712
Kief	307	139	159	135
Kramer	172	190	220	198
Landa	-	140	149	132
Lansford	337	353	300	352
Lignite	214	217	235	230
Maxbass	147	217	215	259
Minot	10,476	16,099	16,577	22,032
Mohall	651	676	687	1,073
Newburg	110	87	119	105
Noonan	376	423	520	551
Norma	-	-	114	-
Omemee	222	170	123	60
Overly	193	134	125	90
Portal	545	542	499	409
Rolette	409	428	460	451
Rolla	675	852	1,008	1,176
Rugby	1,424	1,512	2,215	2,907
St. John	460	372	517	451
Sawyer	241	206	271	264
Sherwood	423	455	390	421
North Dakota (Cont'd)				
Souris	269	248	259	206
Surrey	-	-	250	-
Tolley	325	225	177	248
Towner	610	622	918	955
Upham	196	257	243	403
Velva	836	870	1,017	1,170
Voltaire	-	61	101	72
Westhope	439	521	460	575
Willow City	559	577	524	595
Wolseth	-	-	190	227
Sub total	30,460	37,625	41,730	48,558
Devils Lake Area				
North Dakota				
Alsen	-	358	312	114
Bisbee	500	531	393	365
Brinsmade	191	199	206	136
Brocket	240	276	291	212
Calio	132	152	98	102
Calvin	-	-	300	152
Cando	1,111	1,164	1,282	1,530
Churchs Ferry	353	295	244	223
Clyde	-	-	175	-
Crary	307	278	267	235
Devils Lake	5,140	5,519	6,204	6,427
Doyon	-	-	105	-
Edmore	501	396	453	458
Egeland	306	333	275	248
Hampden	199	222	193	203
Hansboro	218	176	196	134
Knox	173	177	189	190
Lakota	959	860	907	1,032
Lawton	227	233	210	211
Leeds	704	725	782	778
Loma	-	293	256	53
Mapes	-	-	100	-
Minnewaukan	564	480	521	443
Munich	248	260	216	248
Nekoma	189	191	184	140
Perth	218	153	145	124
Rock Lake	238	279	348	385
Starkweather	302	312	295	229
Tokio	-	-	112	-
Webster	-	-	209	-
Wolford	-	-	206	140
York	-	-	337	-
Sub total	13,020	13,862	16,011	14,512
Grand total	43,480	51,487	57,741	63,[illegible]

WATER RESOURCES DEVELOPMENT

Existing Projects

Inadequate water supplies have prevented large scale water programs. Two industrial and 12 wildlife refuge water impoundments have been constructed on the Souris River. Sixteen wildlife reservoirs are on tributaries as follows: Des Lacs River, seven; Wintering River, three; and Willow Creek, six. Stock water ponds and minor pools hold an additional 8,400 acre-feet. Conservation has been practiced to the extent permissible with existing resources (table 6 - General Section). Importation of water from the Missouri Basin would relieve the acute shortage of this vital resource.

Potential Development Projects

A review of potential water and land resources development is presented (see figure 2 - General Section); the plan is subject to change contingent upon future studies. The development of the Souris Valley is based upon importation of Missouri River water for irrigation, municipal water supplies, power, and stream sanitation. Diversions may be made from Fort Peck or Garrison Reservoirs. Studies of land uses and water transmission systems are incomplete. Original plans included the Crosby-Mohall irrigation unit in northwestern North Dakota to receive water from Fort Peck Reservoir and potential Crosby and Des Lacs power plants. Preliminary soil classification studies by the Bureau of Reclamation indicates that land best suited to irrigation lies in the eastern portion of the Sub-Basin along the downstream reaches of the Souris from Velva to the Canadian line. This land may be served by diversions from the Missouri River in Montana or from Garrison Reservoir in North Dakota. Since water routing will affect water supplies and stream sanitation practices of industries and communities in the neighborhood of the development, it is desirable to outline potential plans.

Potential Crosby-Mohall Unit consists of approximately 1,000,000 acres of irrigable land to be supplied by water from Fort Peck and Medicine Lake Reservoirs carried by the Souris Canal. Return irrigation flows would supplement water supplies in the Souris River for industrial, municipal, and stream sanitation purposes particularly below Minot, North Dakota. Return flows from the Crosby-Mohall Unit would restore desirable water levels and reduce salinity in Devils and Stump Lakes, provide municipal water supplies for urban centers along the Sheyenne and Red Rivers, give more adequate flows for stream sanitation in the Red River, and furnish water for irrigation, municipal, and stream sanitation purposes in the James River Valley. The unit includes potential Souris River Diversion Dam near Velva (table S-3), Sheyenne Canal, Cheyenne Dam and Reservoir, Devils Lake Feeder Canal, Stump Lake Feeder Canal, Stump Lake Outlet Canal, and James River Feeder Canal. However, drainage investigations of the Crosby-Mohall make it desirable to survey areas farther east and south for more suitable irrigable lands. The area of greatest promise lies in the eastern portion of the Souris River Basin and contains between 300,000 and 400,000 acres. A second irrigable region has been found in the Carrington-Fessenden-New Rockford-Warwick section of the James River Basin of

North Dakota where more than 100,000 acres may be suitable for development. A third large area of irrigable lands (about 100,000 acres) lies in the James River Basin between Oakes, North Dakota, and Britton and Columbia, South Dakota. A definite plan report for the Crosby-Mohall Unit is scheduled for release by the Bureau of Reclamation in the fall of 1953.

Table S-3. Souris River Sub-Basin - Development program dams[1]

Name:	Souris River Diversion Dam
River mileage:	165 miles above International Boundary on Souris River
Uses:	Irrigation Water Supply Pollution Abatement Recreation Fish and Wildlife
Status:	Proposed

[1] Data from Bureau of Reclamation.

Garrison Reservoir is an alternate source of water. Diversion of water from Garrison Reservoir would be accomplished by pumping to Snake Creek and Turtle Lake Reservoirs. A pumping plant on the latter reservoir would lift water onto the divide between the Missouri and James and Sheyenne River Valleys. Water would then flow through a system of canals, power plants, reservoirs, and natural stream channels to desirable lands in the east central portion of North Dakota. One plan proposes diversion of waters to the Souris River at a point upstream from Minot. This plan is more desirable from a public health viewpoint since municipal water supplies, especially for the City of Minot, would be augmented. Additional water would also provide more dilution for municipal and industrial wastes discharged to the stream. Another plan calls for discharge into the Souris near Velva, with distribution canals running northwesterly from a siphon at that point to serve the area west of the river. East of the river the irrigable land would probably be served by pumping plants along the stream. It is expected that water for domestic supplies, stream sanitation, and other purposes will be available to many of the towns in that part of the Souris River drainage basin.

No irrigation development is currently planned for the Devils Lake area. It is proposed that the lake be restored to an elevation of 1,425 feet m.s.l. with water supplied from either Garrison or Fort Peck Reservoir, and that it be connected with Stump Lakes and the Sheyenne River.

PRESENTATION OF DATA

Municipal Water Supplies

One community in the Sub-Basin, Fish Lake Indian Agency, uses a surface source for its water supply (table S-4). Water secured from Fish Lake is aerated, coagulated, settled, filtered, and chlorinated to serve a population of 450 an average of 45,000 gallons per day.

Table S-4. Souris River Sub-Basin - Municipal surface water supplies

Stream and municipality	Miles upstream: Souris River International Boundary	Miles upstream: Tributary	Treatment[1]	Population served	Average[2] consumption M. G. D.
Souris River					
Willow Creek	57				
Ox Creek		22			
Fish Lake		65			
Fish Lake Indian Agency, N.D.		0	AFD	450	0.045

[1] Treatment - A - Aeration
F - Coagulation, sedimentation, filtration
D - Chlorination

[2] State Health Department Records.

The remaining 23 communities with public supplies derive their water from ground sources--22 from wells and 1 from springs (table S-5). Water is distributed without treatment except at Minot where chlorination is practiced. Minot is installing facilities to secure its water from the Souris River.

Ground water supplies serve a total population of 37,130 with 2.608 million gallons per day. This amounts to 70 gallons per capita per day as compared to 100 gallons per capita generally consumed, possibly reflecting inadequate sources and poor water quality.

Industrial Water Supplies

Many industrial establishments obtain their water needs from municipal systems. Those that secure all or part of water needs from private sources are shown in tables S-6 and S-7. A sand and gravel company pumps 540,000 gallons daily from the Souris River, two power plants use the river for cooling water, and 12 establishments utilize 617,000 gallons per day from wells.

Table S-5. Souris River Sub-Basin - Municipal ground water supplies

Municipality	State	Source[1]	Treat-ment[2]	Population served	Average consumption M.G.D.[4]
Souris Valley					
Belcourt	N.D.	W	N	250[a]	0.020[a]
Bottineau	N.D.	W	N	1,680	0.357
Bowbells	N.D.	W	N	500	0.015
Columbus	N.D.	W	N	300[a]	0.020[a]
Crosby	N.D.	W	N	1,600	0.050
Drake	N.D.	W	N	1,050	0.025
Dunseith	N.D.	W	N	370	0.020
Kenmare	N.D.	W	N	1,200	0.100
Minot	N.D.	W[3]	D	15,400	1.150
Mohall	N.D.	W	N	880	0.060
Noonan	N.D.	W	N	280	0.020
Rolette	N.D.	W	N	100	0.015
Rolla	N.D.	W	N	900	0.060
Rugby	N.D.	W	N	1,750	0.075
Sanhaven	N.D.	W	N	500	0.050
Towner	N.D.	W	N	600	0.060
Velva	N.D.	Sp.	N	1,110	0.060
Westhope	N.D.	W	N	480	0.026
Subtotal				28,950	2.183
Devils Lake Area					
Cando	N.D.	W	N	1,280[a]	0.080[a]
Devils Lake	N.D.	W	N	5,000	0.260
Fort Totten	N.D.	W	N	100[a]	0.005[a]
Lakota	N.D.	W	N	800	0.035
Leeds	N.D.	W	N	1,000	0.045
Subtotal				8,180	0.425
TOTAL				37,130	2.608

---

[1] Source - W - Wells
Sp. - Springs
[2] Treatment - N - None
D - Chlorinated
[3] Minot is installing facilities to take water from the Souris River.
[4] State Health Department Records.
[a] Estimated.

Table S-6. Souris River Sub-Basin - Industrial surface water supplies.

Stream and industry	Location	Miles upstream Souris River International Boundary	Average consumption gallons per day
Souris River			
Minot Sand and Gravel Co.	Minot, N.D.	230.0	540,000
Power Plant	Minot, N.D.	-	-
Co-Op. Power Plant	Logan, N.D.	212.0	-

Table S-7. Souris River Sub-Basin - Industrial ground water supplies

Industry	Location	Average consumption gallons per day
Drake Co-Op Creamery Co.	Drake, N.D.	8,000
Eatmore Sausage Co.	Minot, N.D.	10,000
Fairmount Foods	Devils Lake, N.D.	1,600
Great Northern Railroad	Minot, N.D.	500,000
Joe Feist Processing	Velva, N.D.	1,000
Kessler Packing & Locker Plant	Devils Lake, N.D.	1,600
Lakota Creamery Co.	Lakota, N.D.	8,000[a]
Minot Abattoir	Minot, N.D.	2,000[a]
Minot Creamery	Minot, N.D.	5,000[a]
Mohall Creamery	Mohall, N.D.	5,800
North West Rendering Co.	Minot, N.D.	20,000[a]
Rugby Creamery	Rugby, N.D.	54,000
	Total	617,000

[a] Estimated.

Pollution Contributed to Water Resources

Basic data on sources of municipal pollution are presented in table S-8. Fifteen sewered municipalities in the Souris Valley serve a population of 34,120 and, in addition, collect wastes from industry equivalent to a population of 14,550. Treatment reduces pollution discharged 43 percent, to a population equivalent of 27,520. Because of local drainage characteristics, a population equivalent of only 17,920 generally reaches flowing watercourses. Four of the 11 communities providing sewage treatment employ septic tanks which are generally recognized by the North Dakota State Department of Health as inadequate for treatment of municipal wastes. Five communities have primary and two have secondary treatment plants.

The Devils Lake area has four sewered communities. All provide treatment, although two employ septic tanks which are considered unsatisfactory for disposal of wastes from these two municipalities. The waste

Table S-8. Souris River Sub-Basin - Basic data on sources of municipal pollution

Stream and Municipality	Miles upstream		Population served by sewers	Population equivalent (B.O.D.) untreated waste[1]	Waste treatment provided	Adequacy of treatment facilities		Population equivalent discharged to watercourse[1]	Project needs	Current status municipal action
	Souris River International Boundary	Tributary				Cap'y	Oper.			
Souris River										
Long Creek	Int.Boundary									
Nameless Creek		30								
Crosby, N.D.		12	1,500	1,680	Minor[a]	Unsat.	Sat.	(1,430)[b]	New plant	Inactive
Nameless Creek		8								
Noonan, N.D.		22	280	280	Primary	Sat.	Unsat.	(280)[b]	None	-
Short Creek	Int.Boundary									
West Br.Short Cr.	" "									
Nameless Creek		7								
Columbus, N.D.		10	300	300	Primary	Sat.	Sat.	(200)[c]	None	-
Des Lacs River	242.5									
Stony Creek		66								
Bowbells, N.D.		7	500	650	Primary	Sat.	Unsat.	(420)[c]	None	-
Kenmare, N.D.		56	1,200	3,500	None	-	-	3,500	New plant	Inactive
Minot, N.D.	220		20,000	27,500	Secondary	Unsat.	Sat.	11,000	Replacement	Under const.
Velva, N.D.	178		1,110	1,320	None	-	-	1,320	New plant	Inactive
Wintering River	130.5									
Drake, N.D.		30	1,050	1,350	Minor[a]	Unsat.	Unsat.	(1,350)[b]	New plant	Inactive
Towner, N.D.	102		600	1,600	None	-	-	1,600	New plant	Inactive
Willow Creek	57									
Ox Creek		22								
Rolla, N.D.		63	1,200	1,200	Minor[a]	Unsat.	Unsat.	(1,200)[b]	New plant	Inactive
Belcourt, N.D.		57	400	400	Primary	Sat.	Sat.	(250)[c]	None	-
Oak Creek		13								
Bottineau, N.D.		21	1,680	3,520	Primary	Sat.	Sat.	(2,300)[c]	None	-
Snake Creek		6								
Nameless Creek		30								
Rugby, N.D.		12	3,000	3,600	Secondary	Sat.	Sat.	(900)[b]	None	-
Cut Bank Creek	28.2									
Deep Creek		16								
Spring Coulee		7								
Mohall, N.D.		60	800	1,270	Minor[a]	Unsat.	Unsat.	(1,270)[c]	New plant	Inactive
Nameless Coulee	15									
Westhope, N.D.		3	500	500	None	-	-	500	New plant	Active planning
Subtotal			34,120	48,670				27,520 (17,920)[d]		
Devils Lake Area										
Cando, N.D.	Not applicable no defined drainage		1,500	3,120	Minor[a]	Unsat.	Unsat.	(2,650)[b]	New plant	Inactive
Devils Lake, N.D.			5,000	11,650	Minor[a]	Unsat.	Unsat.	10,000	New plant	Inactive
Lakota, N.D.			1,100	1,660	Lagoon	Sat.	Sat.	e	None	-
Leeds, N.D.			1,000	1,000	Primary	Sat.	Unsat.	1,000	None	-
Subtotal			8,600	17,430				13,650 (11,000)[d]		
Total			42,720	66,100				41,170 (12,250)[d]		

[1] Includes organic industrial wastes discharging to municipal systems.

[a] Septic tank.

[b] Discharge to slough - drainage to watercourse indefinite or nonexistent and primarily of local significance.

[c] Discharge to intermittent creek - pollution reaches watercourse only during periods of high water.

[d] Wastes generally not reaching flowing watercourses.

[e] Discharge to an artificial lagoon - no outlet to watercourse.

produced is equivalent to a population of 17,430, about one-half from domestic and one-half from industrial sources. Treatment reduces oxygen consuming wastes 22 percent to a population equivalent of 13,650. However, a population equivalent of only 11,000 generally reaches surface waters as a population equivalent of 2,650 originates in landlocked indefinite drainage areas or are discharged to artificial lagoons.

Treatment in the entire Sub-Basin reduces the population equivalent of municipal wastes from 66,100 to 41,170, or 38 percent. Seventy-nine percent, or 15 of 19 cities, provide some form of treatment as compared to the national average of 61 percent. However, as 6 of 15 plants are septic tanks producing at best minor treatment, only 47 percent of the communities have reasonable treatment facilities.

Table S-9 depicts industrial pollution in the Sub-Basin. Three of the 11 sources of industrial pollution drain waters from lignite mines. With the exception of a sand and gravel company, the remaining are food processing industries having an organic waste load with a population equivalent of 4,010. Treatment at 4 of the 7 plants reduced over-all pollution 40 percent to a population equivalent of 2,400.

Low Flow Frequencies

A brief study of past stream discharges was made to determine the future expectancies of low flows for summer months (June-September) and winter months (December-February) - table S-10. The minimum average monthly flow for these periods for the years of record was chosen and used in determinations. Low flow frequencies are utilized as a basis for sewage treatment works design and to predict recurrences of poor sanitary conditions in the stream.

It is not uncommon for the Souris River to have flows which approach and even reach zero for prolonged periods. Ordinarily stream pollution is most severe during summer months due to diminished stream discharges and high temperatures. Stream flows may also be at a minimum during winter months.

Data is lacking on runoff of small streams contributing to lakes in the Devils Lake area, but it is assumed that flows reach zero each year.

Laboratory Results

Climatic conditions impose two critical periods upon streams in relation to contributed pollution. During the high temperature-low flow period, oxygen consuming substances may reduce dissolved oxygen to levels where fish life is imperiled or destroyed and nuisance conditions enhanced. Also, when complete ice cover prevents reaeration, conditions of oxygen deficiency may exist.

Field sampling and laboratory analyses were conducted by the State Department of Health of North Dakota during the critical periods. Average analytical results together with diagrammatic presentation of sources of pollution and their waste discharges to streams are

Table S-9. Souris River Sub-Basin - Basic data on sources of industrial pollution - Industries discharging wastes directly to watercourse

Stream and industry	Miles upstream		Type of industry	Type of waste produced	Population equivalent (B.O.D.) untreated waste	Treatment or other pollution control measure			Population equivalent discharged to watercourse	Pollution abatement needs or equiv. control measures	Current status industrial action
	Souris River International Boundary	Tributary				Degree	Adequacy Cap'y	Oper.			
Souris River											
Short Creek											
W.Branch Short Cr.											
Baukal Moonan, Inc. Near Noonan, N.D.		15	Lignite mining	Mine drainage	Not applicable	None	-	-	(c)	None	-
Nameless Creek		7									
Columbus Cold Storage, Columbus, N.D.		10	Food prod.	Organic	280	(a)	Sat.	Sat.	None	None	-
Tributary		6									
Truax Coal Co. Near Columbus, N.D.		10	Lignite mining	Mine drainage	Not applicable	None	-	-	(c)	None	-
Minot Sand & Gravel Co. Minot, N.D.	232		Sand and gravel	Inorganic	Not applicable	Primary	Sat.	Sat.	Not applicable	None	-
Minot Abattoir, Minot, N.D.	230		Food prod.	Organic	280	None	-	-	280	Connect to municipal system	Inactive
Northwest Rendering Co. Minot, N.D.	225		Food prod.	Organic	1,000	(b)	Sat.	Sat.	None	None	-
Eatmore Sausage Co. Minot, N.D.	220		Food prod.	Organic	1,940	None	-	-	1,940	Connect to municipal system	Inactive
Truax Mining Co. Velva, N.D.	188		Lignite mining	Mine drainage	Not applicable	None	-	-	Not applicable	New plant	Inactive
Joe Feist Velva, N.D.	178		Food prod.	Organic	180	None	-	-	180	New plant	Inactive
Willow Creek	57										
Snake Creek		6									
Nameless Creek		30									
Red Owl Agency Rugby, N.D.		12	Food Prod.	Organic	160	(a)	Sat.	Sat.	None	None	-
Cut Bank Creek	29										
Sherwood Creamery Assoc. Sherwood, N.D.	Landlocked	110	Food prod.	Organic	170	(a)	Sat.	Sat.	None	None	-
		Total			4,010				2,400		

a. Land application. b. Lagoon. c. Discharge to intermittent creek - pollution reaches watercourse only during periods of high water

Table S-10. Souris River Sub-Basin - Probable frequency of low mean monthly flows

Years of Record[1]	Stream and location	Drainage area square miles	Low mean monthly discharge in c.f.s. that may be expected once in: 2 yrs.	3 yrs.	5 yrs.	10 yrs.	Low mean monthly flow of record
			SUMMER (JUNE-SEPT)				
47	Souris River above Minot, N.D.	11,300	6.3	1.0	0.3	0.0	0.0
18	Souris River near Westhope, N.D.	17,600	9.1	3.7	0.8	0.0	0.0
			WINTER (DEC-FEB)				
37	Souris River above Minot, N.D.	11,300	0.6	0.5	0.1	0.0	0.0
13	Souris River near Westhope, N.D.	17,600	0.0	0.0	0.0	0.0	0.0

---

[1] Based upon U.S.G.S. records.

illustrated in figures S-1 and S-2. The waste loading includes both municipal and industrial pollution. A summary of laboratory data, as well as stream discharges, is included in appendix F.

Sampling stations were selected to evaluate stream conditions in the Souris River from Canada through northern North Dakota and back into Canada. Stations were selected above and below major sources of pollution, at existing impoundments, and on the major tributary. Twelve stations were established at river mile locations given in the summary appendix. Five collections were made during August 1950, and four collections in January-February 1951. The summer group totaled 240 samples on which 420 analyses were conducted; the winter study, 162 samples with 316 analyses. Stream flows at times of sampling are recorded with summary data.

Average summer results of sampling (figure S-1) at the first station downstream from the International Boundary indicate a moderate B.O.D. of 4.4 ppm. with dissolved oxygen content at 65 percent saturation (6.0 ppm.). It would appear that this situation results from natural stream conditions, wildlife pollution, and decaying organic growths in the reservoir above USBS Dam 41. The increase in B.O.D. and median coliform count at the second downstream station (still above the dam) indicates some influence by waterfowl.

As water passed through the upper series of USBS dams, some improvement occurred. Dissolved oxygen increased to 8.2 ppm. or 87 percent saturation, and B.O.D. dropped considerably from its peak.

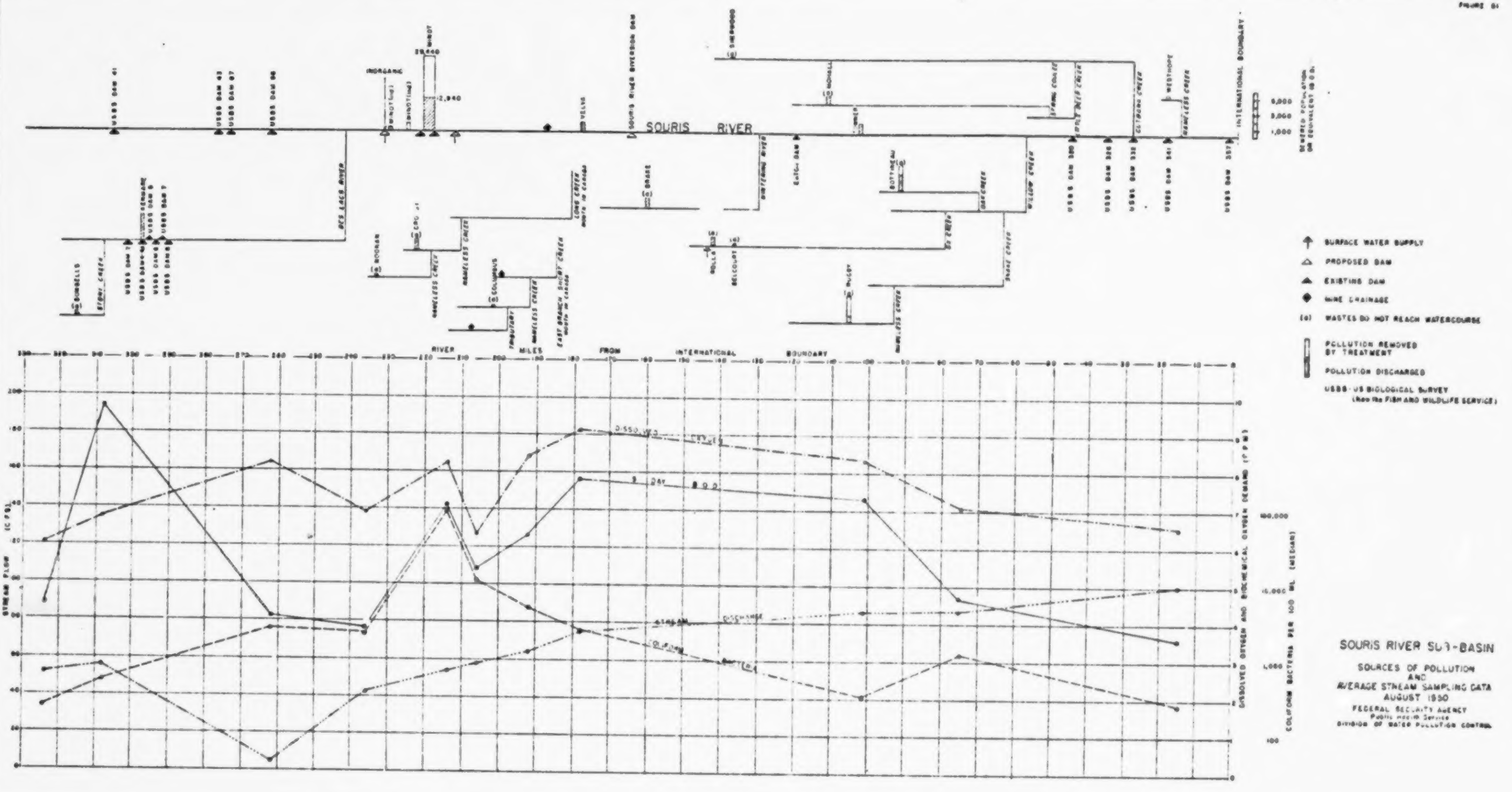
The station on the Des Lacs River showed a high B.O.D. (7.8 ppm.) probably caused by organic matter in return waters from irrigated lands and from natural sources, and an oxygen value of 6.2 ppm. The entrance of this water into the Souris River increased flow in the latter and lowered dissolved oxygen.

The pollution contributed by Minot raised B.O.D. to 7.1 ppm. and coliform count to 92,000 M.P.N. per 100 ml. With the exception of the second station below Minot, dissolved oxygen and B.O.D. remained at high levels of about 8.5 ppm. and 7.5 ppm., respectively, until river mile 100 where both showed a gradual and consistent decline. The coliform count stayed at a level generally below 5,000 M.P.N. per 100 ml.

The Souris River, during the summer sampling (figure S-1) presented a picture of a moderately polluted stream still capable of maintaining satisfactory dissolved oxygen levels. It should be emphasized that stream discharges below Minot, ranging from 60 to 100 c.f.s., were far above the normal low flows. Under normal low flows, critical conditions can be anticipated with existing pollution.

Figure S-2 illustrates stream conditions under ice cover, which is generally completed and endures over the entire winter season. The Souris River entered North Dakota with an average dissolved oxygen value of 0.7 ppm. or 5 percent saturation and a B.O.D. of 2.7 ppm. The low dissolved oxygen content is the result of decomposition of organic matter under ice cover. Passage of the stream through the

FIGURE [illegible]



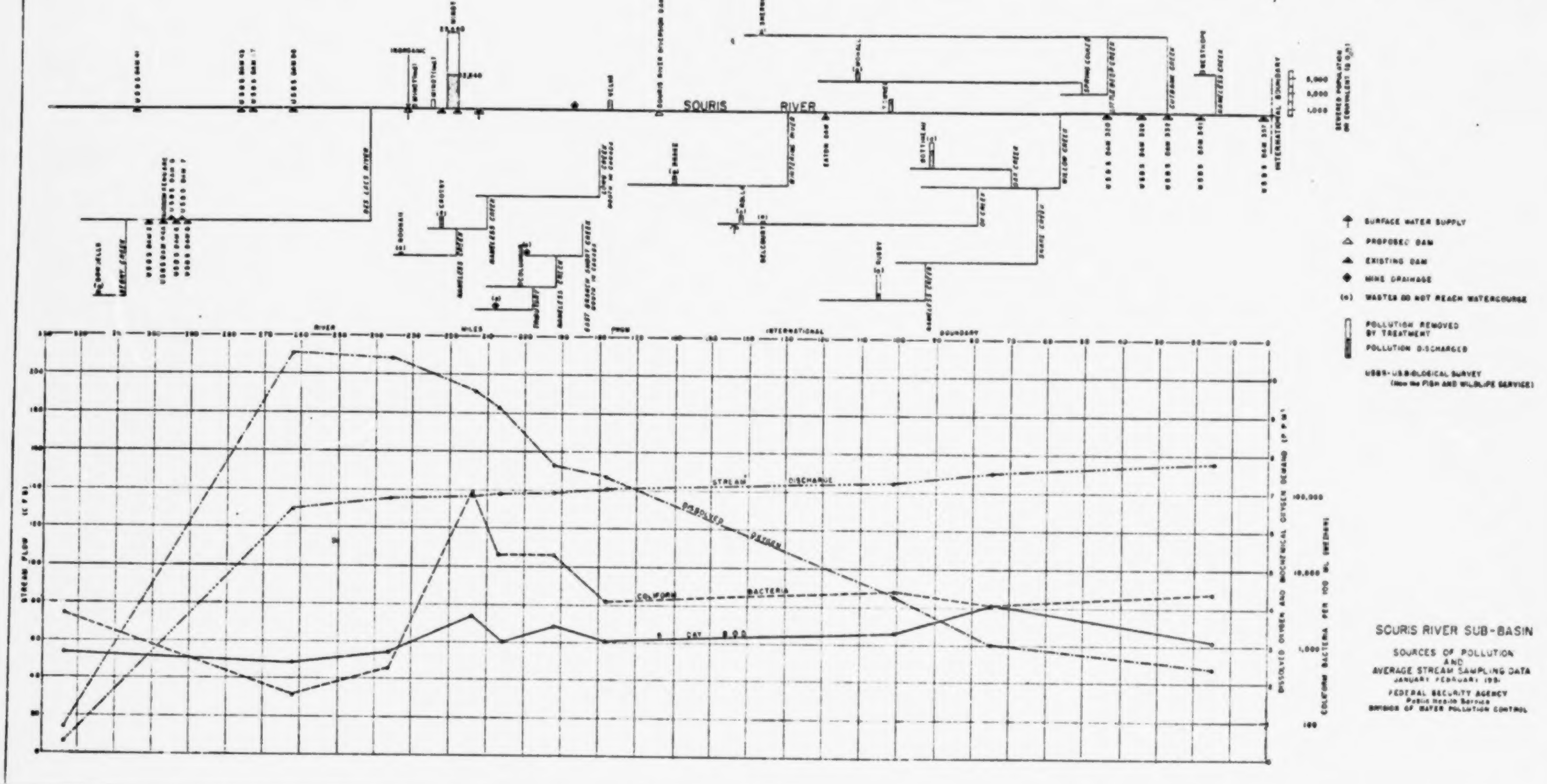
SOURIS RIVER SUB-BASIN

SOURCES OF POLLUTION
AND
AVERAGE STREAM SAMPLING DATA
AUGUST 1950

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

130-A

FIGURE [illegible]



- ↑ SURFACE WATER SUPPLY
- △ PROPOSED DAM
- ▲ EXISTING DAM
- ◆ MINE DRAINAGE
- (o) WASTES DO NOT REACH WATERCOURSE
- ▯ POLLUTION REMOVED BY TREATMENT
- ▮ POLLUTION DISCHARGED

USBS - U.S. BIOLOGICAL SURVEY
(Now the FISH AND WILDLIFE SERVICE)

SOURIS RIVER SUB-BASIN

SOURCES OF POLLUTION
AND
AVERAGE STREAM SAMPLING DATA
JANUARY FEBRUARY 1951

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

upper series of USBS dams improved water quality considerably. Dissolved oxygen increased to 10.5 ppm., or 72 percent saturation, while B.O.D. and median coliform counts decreased.

Pollution contributed by Minot decreased dissolved oxygen, increased B.O.D. to 3.7 ppm. and raised coliform count to 92,000 M.P.N. per 100 ml. Dissolved oxygen continued to decrease under ice cover as flow progressed downstream until a low of 2.4 ppm. (16 percent saturation) was reached at the last sampling station. B.O.D. remained fairly constant at a moderate level and the coliform count, following a sharp decline after the peak at Minot, stayed moderately low. The downstream series of USBS dams appeared to have little effect.

Decrease in alkalinity from 397 ppm. above to 255 ppm. below the upper dams indicated a reduction in hardness due to biological activity in the reservoirs. Alkalinity increased downstream to a high of 315 ppm. at the last station. The lower dams had little effect upon alkalinity.

DISCUSSION

Surface waters are impounded for industrial water supplies, fish and wildlife conservation, stock watering, recreation, and a small amount of irrigation.

A large part of the river water supply originates in and returns to Canada giving the stream an international character which must be considered in any major development of the area. Flow of the river is highly variable. Runoff from the surrounding prairie is erratic, and amounts to little during the greater part of the year. Occasional floods occur during the snow melting season.

Municipal Water Supplies

Public water supplies are obtained almost exclusively from ground sources. An urban population of 37,130, using 2.608 M.G.D. or approximately 70 gallons per capita per day, is served by ground water. Water shortages occur in many communities and highly mineralized waters are quite general. In fact, problems usually associated with municipal supplies are heavy concentrations of dissolved solids and lack of adequate yields from wells.

The solution of existing water supply problems appears to be in more effective utilization of surface water sources which will involve treatment works necessary to assure a safe, potable water. Pollution abatement and control will assume increasing importance as communities switch to streams for water supplies. The Souris is also a source of ice for commercial and domestic purposes which require a product of safe bacteriological quality.

Table S-11. Souris River Sub-Basin - Communities which may derive water supply benefits by existing and proposed impoundments and diversions[1]

Souris River Valley

North Dakota

Antler
Balta
Bantry
Barton
Bowbells

Burlington
Deering
Donnybrook
Foxholm
Glenburn

Granville
Karlsruhe
Kenmare
Kramer
Lansford

Maxbass
Minot
Northgate
Sawyer
Sherwood

Souris
Surrey
Tolley
Towner
Upham

Velva
Westhope
Willow City

Devils Lake Area

North Dakota

Crary
Devils Lake
Fort Totten
Minnewauken

---

[1] From Bureau of Reclamation.

The development program may help solve the water problems of numerous municipalities. Some may obtain supplies directly from diversion and irrigation canals, others from streams whose flows have been augmented. The dispersion of waters over irrigated lands may raise ground water levels and improve water quality. The Bureau of Reclamation indicated that communities listed in table S-11 may derive water supply benefits from proposed impoundments and diversions. However, the fruition of benefits will depend on flow routing and the results of the conservation program.

Ground waters infiltrated by irrigation seepage may be contaminated by nitrate and phosphate applied to the soil. The relationship between nitrate in water supplies and methemoglobinemia is of public health importance. Tentative standards stating that potable water should not contain more than 10 ppm. nitrate nitrogen have been established by some State health departments. Ground waters should be analyzed for nitrate content prior to usage for domestic consumption. A discussion of nitrates and nitrites in water supplies is presented in appendix D.

Industrial Water Supplies

With the exception of a sand and gravel company and power plants that use the Souris River, industries having private water supplies depend upon wells. Fifteen listed in tables S-6 and S-7 show quite general distribution of industrial water use over the area. Limited industrial water use indicates restricted industrial development.

Irrigation Water Quality

The sanitary quality of waters used to irrigate low-growing garden produce that may be consumed raw is a point of concern to public health authorities. The presence of fecal organisms a short distance below sewage pollution indicates cautious use of these waters. Irrigation waters that may be diverted below sewer outfalls at Minot or Velva may be contaminated with pathogenic organisms unless sewage treatment plant effluent is chlorinated. A partial review of literature on the public health aspects of irrigation with sewage polluted waters is given in appendix C.

Sources of Pollution and Status of Sewage Treatment

A summary of municipal treatment facilities is presented in table S-12. Four communities--Kenmare, Velva, Towner, and Westhope--discharge untreated sewage. Six communities--Crosby, Drake, Rolla, Mohall, Cando, and Devils Lake--have septic tanks which are generally recognized by the North Dakota State Department of Health as unsatisfactory for municipal waste disposal and for practical consideration must be included among those not providing treatment. Sewage originating in Noonan, Columbus, Bowbells, Belcourt, Bottineau, and Leeds is given primary treatment. Secondary treatment is provided at Minot and Rugby while Lakota satisfactorily lagoons its waste which in effect is equivalent to or better than secondary treatment.

An evaluation of the adequacy of treatment facility capacity and operation is given in table S-13. Of 15 municipal treatment units, including septic tanks, the capacity of 7 and the operation of 8 are unsatisfactory. Need for additions to existing plants, new plants, and better operation of sewage treatment plants, is indicated.

Table S-12. Souris River Sub-Basin - Existing municipal* sewage treatment facilities

Degree of treatment provided	Number: Municipalities	Number: Plants	Population served
Minor[a]	6	6	11,050
Primary	6	6	4,160
Secondary	3	3	24,100
No treatment	4	-	3,410

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

[a] Septic tank.

Table S-13. Souris River Sub-Basin - Adequacy of existing waste treatment facilities

Existing treatment facilities	Number	Adequacy with relation to: Capacity: Satisfactory	Capacity: Unsatisfactory	Operation: Satisfactory	Operation: Unsatisfactory
Municipal*	15	8	7	7	8
Industrial**	5	5	0	5	0

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Eleven sources of industrial pollution appear in table S-9. One consists of wastes from a sand and gravel plant, three are mine drainage waters, and seven are wastes from food processing. Mine drainage discharges to intermittent streams in two cases and reaches flowing watercourses only during high water, so its effects are nominal. Settling of the effluent from the sand and gravel company satisfactorily withholds suspended matter from the stream. The mine drainage at Velva should be treated or controlled to eliminate any adverse effect upon the stream. Four food processing wastes are satisfactorily treated and three are discharged without treatment. The adequacy of existing industrial treatment facilities (table S-13) indicates that five plants have adequate capacity and operation.

Stream and Lake Conditions

Souris River

The Souris River is a drift prairie stream with little slope and very slow flow. The river bottom in general consists of a varying mixture of mud and muck with gravel and shingle bars occurring at infrequent intervals. Water color is usually high, indicating swamp or marsh drainage. The river channel occupies a narrow strip of valley, through which it has a tortuous course.

Both the Souris and Des Lacs Rivers have been impounded in part to form lakes for migratory waterfowl refuges. On the Souris, refuges occur on both the descending and ascending arms of the loop into the United States. Major impoundments on the Des Lacs River are just above and below Kenmare, North Dakota. The uppermost Des Lacs impoundment utilizes a raised dike and control structures at the outlet of a natural lake. Impoundments on the Souris were all made by damming the river.

Reservoirs have influenced natural characteristics of both streams, although they appear to have resulted in more modification of the Souris than the Des Lacs. The Upper Des Lacs Reservoir, the major impoundment on that stream, has a maximum depth of 15 feet and an area of 4,650 acres. Total area of all Des Lacs impoundments is 6,500 acres. Water levels are regulated to provide the most favorable conditions for waterfowl. The Des Lacs River is an intermittent stream. Runoff and stream flow result, in normal years, from spring melting of snow and early summer rainfall; flow usually ceases in July. Below the refuge area the Des Lacs has been dammed twice for irrigation pruposes. Both of these dams are rock and concrete structures, one four miles above Burlington, and the other at Carpio.

The largest impoundment on the Souris River, Lake Darling, is located upstream from Foxholm. Impoundments for the Lower Souris Migratory Waterfowl Refuge end in the vicinity of Westhope. The Souris is occasionally an intermittent stream, but this condition at and below Minot may be alleviated by releases from Lake Darling. Two power plants, one at the Minot roundhouse and one near Logan, utilize Souris River water and upon occasion pass most of the flow in the river through their cooling systems. Stretches of the stream remain open below the outlets of both plants in even the coldest weather. Small open water areas during winter periods are also maintained by springs in the vicinity of Velva.

There are few available records concerning the basic water chemistry of the Souris Sub-Basin. Alkalinities recorded during January 1951 varied from means of 255 to 397 ppm. in the Souris, and averaged 486 ppm. in the Des Lacs River near Foxholm. Higher alkalinity values in the Souris occurred at both the upper and lower ends of the North Dakota loop. Lake Darling reduced total alkalinity from 397 to 255 ppm. A gradual build-up occurring downstream was climaxed by an abrupt rise in the last two impoundments of the lower refuge. Reduction of alkalinity is to be expected in a reservoir but causes for its increase in the lower lakes are not apparent. Considerable fluctuation in Souris River water level over the winter months was indicated by as many as four separate layers of ice in certain areas during February 1951.

Dissolved oxygen and B.O.D. relationships during July 1950 show influences of a high plankton population. Phytoplankters raise oxygen levels in a stream by photosynthesis, but in themselves have an oxygen demand in the absence of light. Because the B.O.D. incubation period is conducted in darkness, B.O.D. results include this oxygen demand by phytoplankters.. Therefore, oxygen and B.O.D. peaks and depressions usually occur simultaneously in a stream supporting a significant plankton population. Figure S-1 shows that this condition characterized the Souris River during July 1950, with only one exception. The exceptional case occurred at river mile 262 where there was an average of less than 10 second-feet flow during the sampling period. Extreme low flow would favor development of benthic algae from which very few organisms would be included in B.O.D. samples; hence the marked effect upon oxygen level with little influence upon B.O.D. The significance of B.O.D. determinations as a measure of stream conditions fades with increasing plankton densities.

The oxygen-B.O.D. picture of the Souris was apparently influenced to a marked degree by waterfowl impoundments. Organic matter from animal and plant sources retained in the reservoirs kept oxygen levels below the saturation point despite photosynthetic activities by great concentrations of phytoplankters. Products arising from decomposition of waterfowl feces and other materials in the impoundments evidently had a great stimulus upon plankton growth.

Oxygen levels during July 1951 indicate a greater density of plankton in the river between the upper and lower refuges than in the impoundments themselves (see below). The sharp drop in dissolved oxygen content at river mile 208 below Minot was probably caused by the warming of river water in its passage through the power plant at Logan. The decline at river mile 236 (above Minot) is not readily understandable.

Winter ice cover imposes very severe conditions on the Des Lacs River and its reservoirs where fish apparently survive only in Middle Des Lacs Lake. Ice cover on the Souris brings about considerable oxygen reduction in the impoundments (figure S-2), and at some points on the river between the upper and lower refuges. In January 1951 an abrupt oxygen gain occurred just below Lake Darling and quantities of this gas in solution remained relatively high in the stretch above and below Minot. Flow in the river below Lake Darling varied from 130 to 155 second-feet during that sampling period, and conditions encountered then were not characteristic of the river during periods of lower flow under ice cover.

Biological Features - Plankton samples collected in the Souris River and tributaries in the summer of 1950 showed great concentrations of plankton below Lake Darling. The dominant organism in the river at that time was *Aphanizomenon*. Concentration in the river (102,500,000 organisms per liter) was slightly more than four times the concentration found in Lake Darling (24,750,000 organisms per liter). These facts may serve in some measure to account for higher oxygen levels in the river between the two refuges than in the reservoirs themselves. Lower Des Lacs Lake exhibited a density of plankton organisms amounting to 62,000,000 per liter with *Aphanizomenon* the dominant form, but the Upper and Middle Des Lacs Lakes, with densities ranging from 21,200,000 to 25,040,000 organisms per liter, contained *Microcystis* as the dominant form.

No studies of bottom organisms were conducted. The Fish and Wildlife Service reports that fishing is of little consequence in the Des Lacs River due to a high percentage of winter kill in the Upper Des Lacs Lake and to the fact that the irrigation dams at Burlington and Carpio usually serve as effective barriers to upstream migration of fish from the Souris River. Limited information indicates that fishing in the Souris is not important. Some walleyed and northern pike are taken in Lake Darling and vicinity. The Lower Des Lacs Lake supports no fish population, and it is doubtful that fish are able to survive in the upper lake on this river. Middle Des Lacs Lake contains a small number of bullheads, minnows, suckers, and sticklebacks.

Devils Lake Area

Water conditions in Devils and Stump Lakes have progressively deteriorated with declining water levels. Devils Lake once supported a very fine fish population, principally northern pike, that were occasionally shipped to market in carload lots. Pike disappeared from the lakes about fifty years ago and brook sticklebacks and blunthead minnows survived for about ten years longer. At present there are no fish existing in any of the smaller remnants of both lakes.

Several theories that have been advanced to account for the disappearance of fish from the lakes are individually inadequate to explain the phenomenon. Several interrelated factors, all of which are directly or indirectly related to water level recession, need be considered. An important factor is certainly the great increases in concentrations of various salts that have continued steadily through the years. Cessation of year-round inflow (principally through Mauvais Coulee) coincided with disappearance of the abundant fish population. Analyses during 1949 and 1950 show total dissolved solids varying from 6,280 to 14,800 ppm. in Devils Lake, from 35,100 to 41,900 ppm. in East Devils Lake, from 93,300 to 102,000 ppm. in East Stump Lake, and from 2,410 to 6,090 ppm. in West Stump Lake. Concentrations of dissolved solids that will permit existence of fishes are less than 7,000 ppm.

The U. S. Geological Survey reports that several years ago zinc in concentrations up to 17 ppm. occurred in Devils Lake, but recent analysis indicate only 0.17 ppm. Analyses of lake bottom crusts showed them to have a high zinc content, and it seems likely that zinc has been precipitated from lake water. Apparently present concentrations of various substances serve as no reliable guide to their past history, and theories concerning causes for fish disappearance will likely never advance beyond the speculative stage. It is possible that some nonchemical factor, such as aggravated rate of winter kill occasioned by falling water levels, aided fish eradication. Restocking of fish in Devils Lake has met with no success, even when attempts were made to acclimatize various species to lake conditions before their release. If the Missouri River Basin development plan supplies water to restore levels in these lakes at 1,425 feet, m.s.l., the elevation at which fish disappeared, it will not automatically assure conditions conducive to development of a fish population. Concentrations of dissolved solids in the lakes must be reduced, but the extent of their reduction by dilution will depend upon the quality of water diverted for the purpose. It seems likely that desirable dilution may be assured only by maintaining a fairly constant flow through the lakes, at least for a rather prolonged period during early stages of restoration. This plan would result in increased salt concentrations in streams receiving discharges from the lakes, and regulation of flow from Devils Lake to permit discharges during high stages of recipient streams will be desirable. Planning these discharges will necessitate study of dissolved solids content of all streams concerned as well as Devils and Stump Lakes after their dilution with water provided by the Missouri-Souris plan.

Sewage and Waste Treatment Needs

Since it is to the benefit of local and State interests to maintain optimum stream conditions to protect public health and prevent nuisance conditions, severe pollution will generally be abated. Critical conditions can be alleviated by installation of adequate treatment plants. Treatment required will depend upon the nature and site of contributed wastes, flow conditions, and downstream water uses. Primary treatment to remove settleable solids and floating matter is regarded by the North Dakota State Department of Health as a minimum requirement with existing water uses. When normal minimum flows are below the limit required for the dilution of primary treatment effluents, efficient secondary treatment is considered necessary. Normal minimum flow is defined in this report as the low stream discharge occurring at such a frequency as to form a firm basis for sewage treatment design, generally the minimum mean monthly flow expected once in ten years, selected to protect stream conditions and water use. Downstream uses, such as public water and ice supply, irrigation, and recreation, may necessitate disinfection of sewage treatment plant effluents.

Sewage and waste treatment needs are listed in table S-14. These recommendations are founded upon conditions observed during this investigation, coupled with analyses of available discharge records, and do not reflect a possible increase or decrease in minimum flow resulting from the water resource development program.

Table S-14. Souris River Sub-Basin - Project list

Name	Population equivalent	Treatment		
		Existing	Needs (or equivalent industrial waste control measures)	Project
North Dakota				
Crosby	1,680	Minor[a]	Secondary	New plant
Kenmare	3,500	None	Secondary	New plant
Minot	27,500	Secondary	Add'l.treatment	Replacement
Minot Abbatoir	280	None	Secondary	Connect to municipal system
Eatmore Sausage Company	1,940	None	Secondary	Connect to municipal system
Velva	1,320	None	Secondary	New plant
Truax Mining Co.	Not applicable	None	-	New plant
Joe Feist	180	None	Secondary	New plant
Drake	1,350	Minor[a]	Secondary	New plant
Towner	1,600	None	Secondary	New plant
Rolla	1,200	Minor[a]	Secondary	New plant
Mohall	1,270	Minor[a]	Secondary	New plant
Westhope	500	None	Secondary	New plant
Cando	3,120	Minor[a]	Secondary	New plant
Devils Lake	11,650	Minor[a]	Secondary	New plant

[a] Septic tank.

Secondary treatment facilities as recommended by the State water pollution control agency should be provided by Crosby, Kenmare, Velva, Drake, Towner, Rolla, Mohall, Westhope, Cando, and Devils Lake. Minot, recognizing the need of additional treatment, is replacing its existing secondary treatment plant. Westhope has started to prepare plans for secondary treatment. Industry in the vicinity of Minot may best connect to the municipal system. It is recommended by the State water pollution control agency that the food processing plant near Velva provide secondary treatment. Mine drainage in the vicinity of Velva could be impounded and discharged during high water.

Table S-15 shows that 10 municipalities require new plants, one should replace an existing plant, and 8 require no projects. Four industries need new plants and 7 require no project. No formal action has been taken by 9 municipalities and 4 industries, but 1 municipality has a treatment plant under construction and 1 has plans under way (table S-16). These data indicate the need for aggressive pollution abatement action.

Table S-15. Souris River Sub-Basin - Municipal* and industrial** waste treatment needs

Needs	Municipal		Industrial number
	Number	Population served by facilities	
New plant	10	14,460	4[a]
Enlargement or addition to existing plant	0	-	0
Replace existing plant	1	20,000	0
No project required	8	8,260	7

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

[a] The recommended solution for two of these industries would entail connection to municipal sewerage.

Table S-16. Souris River Sub-Basin - Status of municipal* and industrial** action on pollution abatement needs

Status of project	Number	
	Municipal	Industrial
No formal action	9	4
Abatement ordered	0	0
Plans under preparation	1	0
Final plans approved	0	0
Construction awaiting financing	0	0
Under construction	1	0

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Progress of pollution abatement lagged during and immediately after the war years. No municipal works were constructed in the years 1946-48 (table S-17). One municipal plant was built in 1949 and two in each of the two succeeding years. This might reflect the interest being placed upon pollution abatement by the public, city officials, and State and Federal agencies. No industrial waste treatment plant was constructed during the last six years.

Table S-17. Souris River Sub-Basin - Progress in pollution abatement

	Municipal*		Industrial**	
Year	Plants completed	Design population	Plants completed	Amount of waste treated
1946	0	-	0	-
1947	0	-	0	-
1948	0	-	0	-
1949	1	-	0	-
1950	2	4,000	0	-
1951	2	36,000	0	-

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Flow Needs Evaluation

The water resource development program may increase minimum flows sufficiently to permit a lower degree of sewage treatment, to improve water quality, to increase water available for municipal and industrial uses, and to enhance fish and wildlife propagation. These results would provide tangible monetary benefits to the development projects. Contrariwise, damages may result if water diverted to other uses reduces flows below the required minimum, provided normal flows are equal to or above minimum needs. It may not be assumed that damage will not occur if regulation provides a minimum flow equal to the unregulated minimum previously prevailing, since stream conditions would approach those existing during unregulated minimums and be worse when regulated discharges are less than those naturally occurring.

Primary treatment minimum flows and secondary treatment minimum flows specified in table S-18 are those required to assimilate residual oxygen-consuming matter remaining after the designated degree of waste treatment has been provided, without lowering the oxygen content below that required for balanced aquatic life, normally 5.0 ppm. These flows will provide a basis for comparing the cost of additional treatment against the value of water for other uses. This table also shows tangible annual monetary benefits that would result from the reduced cost of pollution control by lower degrees of sewage treatment with desirable regulation of flow as compared to cost of required waste treatment without flow regulation.

It is not possible to cover adequately in one report all detailed phases of numerous pollution problems. In certain cases more study may be indicated. In some instances large increases in populations at metropolitan centers, new industry, or expansion of existing industry will necessitate revision of specified flows or sewage treatment needs. The development program may realize sizable tangible annual benefits through better stream sanitation where minimum flow needs are met. The City of Minot may benefit to the extent of $46,500 if sustained minimum flows

Table S-18. Souris River Sub-Basin - Flow needs[1] at given locations and cost evaluations

Municipality	Stream	Miles above International Boundary	Minimum normal flow[1] c.f.s.	Primary (35%) treatment minimum flows[1] c.f.s.	Secondary (75%) treatment minimum flows[1] c.f.s.	Annual tangible monetary benefits possible if flow in column 5 provided	Annual tangible monetary benefits possible if flow in column 6 provided
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Minot	Souris	220	0	160	60	46,500	15,500
Velva	Souris	178	0	-*	-*	3,270	1,090
Towner	Souris	102	0	9	4	3,730	1,240

[1] Summer flows

*Flow provided Minot will benefit Velva under present water routing plans.

permit primary sewage treatment. Benefits would accrue to the downstream communities of Velva and Towner. It is estimated that maintenance of minimum flows as specified for the Souris River would provide annual benefits totaling $53,500 if high enough for primary treatment to suffice and $17,830 if nominal secondary treatment is necessary.

Benefits from other water uses would also accrue. Minot is planning to develop a surface water supply from the Souris River in which increased flows and improved water quality would be of tangible benefit. The Municipal Water Supply Unit of the Bureau of Reclamation is appraising such benefits. Fish and wildlife conservation and recreational programs would be enhanced by sustaining reasonable flows. Flow needs, by months, below Minot and Towner are presented in table S-19.

Table S-19. Souris River Sub-Basin - Flow needs in c.f.s., by months for critical locations

	Minot				Towner			
	Present		Future (1980)		Present		Future (1980)	
Month	Primary 35%	Secondary 75%	Primary 45%	Secondary 85%	Primary 35%	Secondary 75%	Primary 45%	Secondary 85%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Jan.	210	100	400	140	13	5	21	6
Feb.	210	100	400	140	13	5	21	6
March	120	60	250	80	9	4	11	4
April	80	30	130	40	5	2	8	2
May	80	30	130	40	5	2	8	2
June	160	60	270	70	9	4	15	4
July	160	60	270	70	9	4	15	4
August	160	60	270	70	9	4	15	4
Sept.	160	60	270	70	9	4	15	4
Oct.	80	30	130	40	5	2	8	2
Nov.	80	30	130	40	5	2	8	2
Dec.	210	100	400	140	13	5	21	6

Table S-19 also shows future estimated flows for the year 1980. These are presented to show probable future ultimate dilution water demands for use in water resource planning. It was assumed that the present pollution load would double in the 30 intervening years and that sewage treatment methods, facilities, and operation would improve. Under these conditions a 10 percent increase in the efficiency of secondary treatment with sufficient plant capacity would adequately handle a 100 percent increase in loading with minor increases in needed flows. However, it is wise to defer future evaluations until such time in the future when flow routing is firm and population and industrial trends as influenced by the development program may be established.

The plan of the Bureau of Reclamation to restore Devils Lake to elevation 1,425 and to connect it with Stump Lake and the Sheyenne River will provide benefits for fish and wildlife and recreation. The Fish and Wildlife Service[1] states: "Diversion of fresh water into Devils Lake provides possibilities for greatly enhancing fish and wildlife values of the area. A fishery of great value could be restored in the lake. Waterfowl and fur animals would also benefit materially by the inflow of fresh water and stabilization of water level."

However, great caution must be exercised in displacing the saline waters of the lakes so that municipal and industrial water supplies obtained from the Sheyenne and Red Rivers are not adversely affected. Some method of controlled discharges to take advantage of high water may be indicated. The Public Health Service Drinking Water Standards (1946) states that the following chemical substances, among others, which may be present in natural or treated waters should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority:

Chloride	-	250 ppm.
Sulfate	-	250 ppm.
Total solids	-	500 ppm.
Magnesium	-	125 ppm.
Zinc	-	15 ppm.
Copper	-	3 ppm.

It is probable that some of the above concentrations might be exceeded during flushing of Devils Lake. Although chlorides will be a problem above 250 ppm. concentrations, sulfates of 500 ppm. and total solids of 1000 ppm. may not interfere appreciably with municipal water supply use.

Data secured by the Water Quality Branch - Water Resources Division, U. S. Geological Survey, Lincoln, Nebraska, shows total solids of lakes in this area to reach 100,000 ppm., sulfate to range over 6000 ppm. Other chemical constituents are also high.

---

[1] "A Preliminary Report on Fish and Wildlife Resources in Relation to the Water Development Plan for Devils Lake and Stump Lake Reservoirs."

RED RIVER SUB-BASIN

TABLE OF CONTENTS

Page

Summary 147
Conclusions 148
Description 149
Water Resource Development 153
    Existing Projects 153
    Potential Development Projects 153
Presentation of Data 156
    Municipal Water Supplies 156
    Industrial Water Supplies 156
    Pollution Contributed to Water Resources 159
    Low Flow Frequencies 163
    Laboratory Results 168
Discussion 171
    Municipal Water Supplies 171
    Industrial Water Supplies 174
    Sources of Pollution and Status of Sewage Treatment . . . 174
    Stream Conditions 177
    Sewage and Waste Treatment Needs 177
    Flow Needs Evaluation 182

Preceding page blank

TABLES AND FIGURES

Table Page

R-1 Principal tributaries and their drainage areas 150
R-2 Population of municipalities 151
R-3 Development program dams 154
R-4 Municipal surface water supplies 157
R-5 Municipal ground water supplies 158
R-6 Industrial surface water supplies 159
R-7 Industrial ground water supplies 160
R-8 Basic data on sources of municipal pollution 161
R-9 Basic data on sources of industrial pollution 164
R-10 Probable frequency of low mean monthly flows 167
R-11 Communities which may derive water supply benefits by existing and proposed impoundments and diversions . . 173
R-12 Existing municipal sewage treatment facilities 175
R-13 Adequacy of existing waste treatment facilities . . . 176
R-14 Project list 179
R-15 Municipal and industrial waste treatment needs 181
R-16 Status of municipal and industrial action on pollution abatement needs 181
R-17 Progress in pollution abatement 182
R-18 Flow needs at given locations and cost evaluation . . . 184
R-19 Flow needs in c.f.s., by months for critical locations . 186

Figure

R-1 Sources of Pollution and Stream Sampling Data August 1950 168
R-2 Sources of Pollution and Stream Sampling Data January 1951 168
R-3 Stream Sampling Data, December 1, 1938, to April 1, 1939, and August 1 to October 1, 1939 170
R-4 Average Monthly Supplemental Flow Needs 185

SUMMARY

The Red River of the North, formed by junction of the Ottertail and Bois de Sioux Rivers, constitutes most of the boundary between the States of Minnesota and North Dakota. It flows north a distance of 394 miles before crossing the International Boundary into Canada. The Red River Valley is a broad level plain varying in width from 15 to 70 miles and sloping almost imperceptibly toward the north. It was once the bed of glacial Lake Agassiz.

Agriculture and its related activities are the principal occupations. Although there are more than 220 municipalities in the Red River Sub-Basin only 10 cities have populations in excess of 5,000. Most communities have less than 500 inhabitants. The Sub-Basin's population is approximated at 490,000.

The shortage of water, either from surface or ground sources, has restricted development of the industrial potential of this Sub-Basin. Agriculture has been affected, but to a lesser degree. The need to conserve stream flows for municipal and industrial water supplies has led to extensive study of the effects of pollution.

Intensive investigation of water resources of the Red River Valley indicate that available water either from surface or ground sources must be supplemented by imported water if an adequate supply is to be insured. The present water-resources development plan calls for regulation of the flow of the Red River and its tributaries with possible augmentation by water from the Missouri River.

Existing water resources are used for municipal and industrial supplies, ice harvesting, hydroelectric power, wildlife refuges, stock watering, recreation, and ultimate disposal of municipal sewage and industrial wastes.

Surface water sources serve 16 municipalities, 7 industrial food processors, and 2 power plants using only cooling water. Ninety-six communities and 100 industrial plants use ground water.

Pollution contributed to the Red River and its tributaries from 90 municipalities and 85 industries has a population equivalent of 468,260 people. Two beet sugar refineries are responsible for 56 percent of the organic material discharged; however, they do not operate on a year-round basis. Seventy-five percent of the sewered municipalities and 65 percent of the industrial establishments provide treatment. The population equivalent strength of municipal waste is reduced by treatment slightly over 50 percent, and that of industry, exclusive of seasonal wastes, is reduced approximately 40 percent.

Thirty-two new municipal sewage treatment plants and 61 new industrial treatment works are considered necessary to prevent or abate pollution. Fifteen municipal plants and three industrial waste treatment works should be enlarged or additional units provided; six municipal plants should be replaced. Cost of constructing the new facilities and improvements is estimated at $6,254,000.

Stream conditions indicate that pollution in the Red River, especially below the Fargo-Moorhead area and the greater Grand Forks area, is sufficient to be of concern. This was reflected in stream analyses even though the flow in the river at the time of study was approximately 10 times as great as that probable low flow expected once each 5 years.

The interstate ramifications have led to the establishment of a formal Tri-State Waters Commission and an informal Interstate Sanitation Committee involving States of North Dakota, Minnesota, and South Dakota, in a cooperative effort to solve the water supply problems of the Basin. The attack on pollution in the area has been led by the latter committee which developed treatment plant effluent standards.

Thirteen new municipal sewage treatment works and one industrial waste treatment facility were constructed in the period 1946 through 1951; one industry has a plant under construction at the present time. Progress in the future may be anticipated as a result of comprehensive programs for pollution abatement and control by the State water pollution control agencies.

The proposed plan to divert water from the Missouri River to supplement supplies in the Red River system will greatly enhance industrial and community growth. Annual benefits exceeding $740,300 are possible and may accrue to water regulatory projects because of savings in waste treatment costs if minimum flows recommended in the report can be provided. Possible benefits from increased flows at specific locations are listed in table R-18. The water requirements upon which the benefits are based are shown in table R-19.

CONCLUSIONS

1. Precipitation in the Red River Basin is inadequate to provide sufficient dependable flows.

2. An efficient water conservation program supplemented by importations from the Missouri River appears necessary if all water requirements are to be satisfied.

3. Municipal and industrial requirements compose the bulk of the present water needs. Dilution of highly treated sanitary and industrial waste is the greatest single usage.

4. Waste produced by 90 municipalities and 85 industries has a population equivalent of 610,350. Seasonal beet sugar refinery wastes account for a population equivalent of 220,000. Omitting seasonal discharges, a population equivalent of 390,350 is reduced 47 percent prior to discharge.

5. The lagooning and controlled release of sugar refining wastes at Moorhead has proven to be an acceptable method of handling this source of pollution.

6. Pollution from the Fargo-Moorhead and Grand Forks-East Grand Forks area is sufficient to reduce the oxygen content of the Red River to levels inimical to aquatic life, to cause odors, and to devaluate its general usefulness.

7. Seventy-five percent of the sewered municipalities of the Basin provide treatment varying from septic tanks to modern secondary facilities.

8. Waste treatment is practiced at 65 percent of the industrial establishments having private outlets. The degree of treatment varies from negligible to secondary or better.

9. Sixteen municipalities of the Basin use surface water resources, many of which have a history of inadequacy. The remainder of the towns (96) derive their water from ground sources. Many of the latter communities have experienced shortages. Most ground waters are highly mineralized.

10. The comprehensive water development plan may provide benefits in the form of improved water supplies and reduced sewage and waste treatment costs.

11. An effective plan for joint administration of the pollution control program for the Red River, including adequate enforcement procedure, is needed.

DESCRIPTION

The Red River of the North, formed by the junction of the Ottertail and Bois de Sioux Rivers at the twin cities of Wahpeton, North Dakota, and Breckenridge, Minnesota, flows northward 394 miles before reaching the International Boundary. Of 35,895 square miles drained by the Red River at the International Boundary, 33,900 square miles are in the United States and the remaining 1,995 square miles are in the Dominion of Canada. The Red River valley is a broad level plain which varies in width from 15 to 70 miles and slopes almost imperceptibly toward the north. Once the valley was the bed of glacial Lake Agassiz. Many tributaries enter from both east and west. Table R-1 lists the principal tributaries and their drainage areas.

Table R-1. Red River Sub-Basin - Principal tributaries and their drainage areas

Stream	Miles upstream International Boundary	Drainage area square miles
Red River		35,895
Bois de Sioux River	393.7	1,967
Ottertail River	393.7	2,048
Wild Rice River, N.D.	315.2	2,210
Sheyenne River	272.3	7,380
Buffalo River	262.5	1,400
Wild Rice River, Minn.	225.4	1,440
Goose River	202.7	1,260
Sandhill River	184*	-
Red Lake River	143	5,711
Turtle River	118.6	700
Forrest River	88	1,000
Snake River	75.2	1,040
Park River	67.3	1,130
Tamarack River	64.6	580
Two Rivers	20.2	776
Pembina River	2.8	3,619

*Estimated.

Agriculture and its concomitant industries are the pillars upon which the Sub-Basin's economy is founded. Field crops and livestock raising contribute largely to farm incomes. Food processing industries are predominant in the larger urban centers. The Missouri River Development Program may expand these industries beyond their present scope with accompanying benefits to the over-all economy.

Population data for 227 municipalities in the Red River Sub-Basin are presented in table R-2. The 10 cities having populations in excess of 5,000 are: Moorhead, Minnesota, 14,870; Fergus Falls, Minnesota, 12,917; Crookston, Minnesota, 7,352; Thief River Falls, Minnesota, 6,926; Detroit Lakes, Minnesota, 5,787; East Grand Forks, Minnesota, 5,049; Fargo, North Dakota, 38,256; Grand Forks, North Dakota, 26,836; Valley City, North Dakota, 6,851; Wahpeton, North Dakota, 5,125. The preponderance of communities have less than 500 inhabitants. Generally, in recent years, rural areas suffered population losses while the larger cities gained in numbers. The population of the Sub-Basin has been estimated at 490,000.

Climate in the Red River Sub-Basin is temperate. Temperatures range from -35° F. to 95° F., with a mean annual temperature of 38.7° F. Mean annual precipitation varies from 16 to 24 inches.

Table R-2. Red River Sub-Basin - Population of municipalities

Municipality	Population - U. S. Census			
	1920	1930	1940	1950
Minnesota				
Ada	1,411	1,285	1,938	2,121
Alvarado	361	323	336	317
Argyle	956	700	857	846
Audubon	314	278	312	275
Badger	394	325	404	448
Bagley	814	885	1,241	1,554
Barnesville	1,564	1,279	1,450	1,593
Battle Lake	628	552	623	714
Bejou	-	99	200	173
Beltrami	219	226	219	199
Blackduck	788	704	753	732
Breckenridge	2,401	2,264	2,745	3,623
Callaway	325	230	249	193
Campbell	424	313	328	391
Clearbrook	310	401	425	539
Climax	274	239	253	271
Clitherall	178	151	172	175
Comstock	-	157	134	139
Crookston	6,825	6,321	7,161	7,352
Dalton	200	182	226	279
Dent	221	224	204	187
Detroit Lakes	3,426	3,675	5,015	5,787
Dilworth	882	983	1,068	1,429
Donaldson	167	133	120	128
Donnelly	354	309	370	396
Doran	98	137	128	126
Dumont	210	186	238	223
East Grand Forks	2,490	2,922	3,511	5,049
Elbow Lake	867	903	1,150	1,398
Elizabeth	204	164	176	168
Erskine	457	511	581	608
Felton	184	137	200	258
Fergus Falls	7,581	9,389	10,848	12,917
Fertile	800	800	907	890
Fisher	305	297	333	302
Fosston	1,014	978	1,271	1,614
Foxhome	266	228	240	217
Frazee	1,277	1,041	1,167	1,021
Gary	333	308	300	278
Georgetown	136	183	193	192
Glyndon	382	388	405	411
Gonvick	276	292	317	375
Goodridge	231	171	174	144
Graceville	1,022	969	1,020	962
Greenbush	310	387	556	713
Grygla	155	147	183	216
Gully	-	138	164	183
Hallock	1,012	869	1,353	1,552
Halma	-	129	158	177
Halstad	528	535	570	635
Hawley	939	958	1,122	1,196
Hendrum	354	326	341	352
Herman	630	518	703	752
Hitterdal	204	198	268	262
Holt	232	193	209	172
Humboldt	198	139	139	143
Johnson	100	96	101	54
Karlstad	286	304	501	804
Kelliher	514	370	357	336
Kennedy	311	279	338	480
Minnesota (Cont'd)				
Kent	150	137	146	178
Lake Bronson	181	239	350	438
Lake Park	700	624	654	689
Lancaster	354	456	473	536
Lengby	170	144	195	206
Leonard	-	109	111	88
McIntosh	805	688	903	881
Mahnomen	1,076	989	1,429	1,464
Middle River	324	275	328	356
Moorhead	5,720	7,651	9,491	14,870
Nashua	127	161	177	181
Newfolden	246	244	300	367
New York Mills	700	667	771	977
Nielsville	-	186	175	189
Norcross	195	163	180	179
Northome	270	258	343	349
Ogema	238	253	328	249
Oklee	364	377	414	494
Oslo	365	328	392	440
Ottertail	223	221	254	237
Pelican Rapids	1,156	1,365	1,560	1,676
Perham	1,370	1,411	1,534	1,926
Perley	222	231	246	204
Plummer	252	279	312	340
Red Lake Falls	1,549	1,386	1,530	1,733
Roseau	1,012	1,028	1,775	2,231
Rothsay	398	386	415	537
Sabin	-	197	210	211
St. Hilaire	346	280	288	276
St. Vincent	343	304	404	272
Shelly	289	308	344	329
Shevlin	184	228	226	242
Stephen	581	474	673	877
Strathcona	-	112	114	143
Thief River Falls	4,685	4,268	6,019	6,926
Tintah	249	192	200	235
Twin Valley	676	657	844	899
Ulen	590	452	562	525
Underwood	258	308	353	336
Vergas	361	323	351	301
Viking	-	133	146	130
Vining	241	222	176	180
Warren	1,772	1,472	1,639	1,779
Waubun	346	337	438	426
Wendell	270	260	273	284
Wheaton	1,337	1,279	1,700	1,948
Winger	-	258	301	283
Wolverton	170	206	222	198
South Dakota				
Newark	190	168	147	80
New Effington	305	337	344	367
Rosholt	301	327	362	387
Veblen	530	520	486	476
White Rock	353	281	220	113

Table R-2. Red River Sub-Basin - Population of municipalities-- Continued

Municipality	Population - U. S. Census			
	1920	1930	1940	1950
North Dakota				
Abercrombie	266	242	215	244
Adams	404	345	355	411
Alice	-	169	181	162
Amenia	-	90	104	127
Anamoose	563	495	478	542
Aneta	662	568	509	469
Ardoch	153	110	119	137
Argusville	-	115	145	126
Arthur	-	322	335	380
Ayr	-	106	107	104
Balta	-	-	263	196
Bathgate	352	292	312	209
Binford	393	317	311	309
Buffalo	268	242	245	261
Buxton	-	410	404	387
Calvin	-	-	300	152
Canton	101	125	148	139
Casselton	1,538	1,253	1,358	1,373
Cavalier	819	850	1,105	1,459
Cayuga	182	219	196	178
Cogswell	445	426	430	393
Conway	148	100	120	107
Cooperstown	1,112	1,053	1,077	1,189
Crystal	349	314	428	429
Davenport	214	205	147	150
Dazey	293	251	215	196
Drayton	637	502	688	875
Dwight	139	104	168	129
Edinburg	278	284	378	343
Elliot	-	106	118	87
Enderlin	1,919	1,839	1,593	1,504
Esmond	343	313	449	475
Fairdale	192	171	187	131
Fairmount	706	611	705	660
Fargo	21,961	28,619	32,580	38,256
Fingal	-	324	300	210
Finley	599	587	677	671
Fordville	320	442	439	376
Forest River	226	198	207	236
Forman	402	386	500	466
Gardner	-	108	103	136
Grafton	2,512	3,136	4,070	4,901
Grand Forks	14,010	17,112	20,228	26,836
Grandin	-	172	158	156
Great Bend	142	169	198	169
Hamilton	200	151	255	241
Hankinson	1,477	1,400	1,420	1,409
Hannaford	431	351	405	313
Hannah	-	262	261	257
Harvey	1,590	2,157	1,851	2,337
Hatton	828	804	933	991
Havana	319	271	305	267
Hillsboro	1,183	1,317	1,338	1,331
Hoople	250	325	346	447
Hope	699	535	474	470
Hunter	424	406	414	417
Inkster	368	257	310	304
Kathryn	289	224	229	200
Kindred	334	429	450	504
Langdon	1,228	1,221	1,546	1,838
North Dakota (Cont'd)				
Lankin	334	267	283	287
Larimore	1,089	979	1,222	1,374
Lidgerwood	1,065	1,029	1,042	1,147
Lisbon	1,855	1,650	1,997	2,031
Litchville	528	410	430	408
Luverne	225	177	187	154
McClusky	646	719	924	850
McVille	546	513	548	626
Maddock	557	631	691	741
Manvel	-	183	209	278
Mapleton	198	195	180	169
Martin	198	211	228	171
Mayville	1,218	1,199	1,351	1,790
Michigan City	491	433	491	486
Milnor	680	564	677	674
Milton	393	329	310	322
Minto	602	565	630	592
Mooreton	123	147	146	161
Mountain	-	-	205	219
Neche	528	502	565	615
Niagara	199	207	179	163
Nome	267	218	277	217
Northwood	935	971	1,063	1,182
Oriska	300	183	217	135
Osnabrock	310	244	269	284
Page	452	443	428	482
Park River	1,114	1,131	1,408	1,692
Pekin	197	210	229	221
Pembina	802	551	703	640
Petersburg	367	310	285	318
Pillsbury	142	260	161	119
Pisek	300	225	242	215
Portland	623	500	551	641
Reynolds	389	351	315	335
Rogers	173	169	174	150
Rutland	291	264	305	309
St. Thomas	500	595	503	566
Sanborn	391	343	366	324
Sarles	348	383	302	285
Sharon	362	328	371	312
Sheldon	321	327	281	267
Sheyenne	-	417	431	469
Southwest Fargo	-	-	707	1,032
Thompson	-	273	276	270
Tolna	199	174	172	281
Tower City	447	435	364	292
Valley City	4,686	5,268	5,917	6,851
Wahpeton	3,069	3,176	3,747	5,125
Wales	-	-	270	235
Walhalla	634	700	1,138	1,463
Warwick	290	249	224	155
West Fargo	-	-	117	159
Wimbledon	521	421	357	449
Wyndmere	570	521	499	627
Totals				
Minnesota	78,207	80,354	97,294	113,856
South Dakota	1,679	1,633	1,559	1,423
North Dakota	92,743	104,462	119,054	137,132
Grand Total	172,629	186,449	217,907	252,411

WATER RESOURCE DEVELOPMENT

Existing Projects

In a region where scant rainfall emphasizes man's dependence upon water resources, it might be anticipated that conservation progress is the byword. To a considerable degree this is true. Results of a water use survey reported to the International Souris-Red River Engineering Committee, International Joint Commission, are summarized in table 6 in the General Section. This table shows that 4,370 acres in the Red River of the North Sub-Basin are irrigated. Topography and drainage characteristics militate against extensive irrigation practice. Industrial and municipal water supplies are taken from 29 impoundments, five on the main stem and the remainder on tributaries (according to the International Joint Commission report). A flood control dam is on the main stem and 13 power impoundments are on tributaries principally from the Minnesota side. There are 30 wildlife refuges generally distributed along tributaries, 46 recreational impoundments credited to Minnesota tributaries and 1,214 stock watering and minor pools on North Dakota tributaries. Apparently, considerable conservation has been made, yet drought years have found water resources depleted.

Potential Development Projects

A review of potential developments included in the comprehensive water conservation plans for this Sub-Basin is presented to indicate the complexity of the program and the interrelation of contemplated water uses. The plan is not final and is subject to change contingent upon future developments. Existing and potential dams forming part of the conservation program are listed in table R-3.

The extreme drought of the 1930 decade impressed upon the residents the vital need for a definite plan of water conservation in the Red River of the North. Since the ground waters of the area are, for the greater part, inadequate in quantity and of poor quality, the conservation program must be one of surface water storage and regulated discharge coupled with importation of additional water.

During the drought many of the tributaries ceased to flow for considerable portions of each year. Even the Red River at Fargo, North Dakota, had extended periods of no flow. Many municipalities in the Basin, including Fargo, the largest city in North Dakota, have been unable to locate an adequate ground water supply and must rely on surface water sources for their municipal needs. During low flow periods the quality of surface waters is very poor, and cities using it are forced into extremely elaborate and costly treatment to keep their drinking water potable. Cattlemen who depended upon the rivers for stock water were forced to haul water for considerable distance or cut down size of their herds. Existing industries were adversely affected and new industry was prevented from developing.

Another problem which confronted municipalities and industries during this period was inadequacy of dilution water in watercourses receiving their wastes.

Table R-3. Red River Sub-Basin - Development program dams[1]

Name	Tributary	River Mileage		Irriga-tion	Flood control	Water Supply	Pollu-tion abate-ment	Recre-ation	Fish and Wild-life	Silt con-trol	Power	Navi-gation	Total capacity acre-feet	Status[2]
		Main Stem	Tribu-tary											
Orwell Dam	Ottertail	393.7	38.6	-	X	X	X	X	-	-	-	-	13,100	U
Lonetree Dam	Sheyenne	272.3	465	X	-	X	X	X	X	-	X	-	-	P
Baldhill Dam	Sheyenne	272.3	270	-	X	X	X	X	X	X	-	-	69,500	E
Homme Dam	Park	67.3	45	-	X	X	X	X	X	X	-	-	3,650	E
Pembina River Dam	Pembina	2.8	90	-	X	X	X	X	X	X	-	-	-	P
Tongue River Dam	Pembina-Tongue	2.8	P-6, T-35	-	X	X	X	X	X	X	-	-	-	P

---

[1] Data from Bureau of Reclamation.

[2] Status - E - Existing
P - Proposed
U - Under construction

Among the plans for alleviating surface water supply shortages, as well as flood control and other beneficial uses, are those of the Bureau of Reclamation and the Corps of Engineers. The Bureau of Reclamation plan entails diverting water from Fort Peck and/or Garrison Reservoir. The Corps of Engineers' plan, on the other hand, proposes to utilize the resources of the Red River Basin with possible later diversion of additional water from Garrison Reservoir.

The Coordinated Water Plan of the Corps of Engineers embraces the Baldhill Dam and Reservoir on the Sheyenne River, the Orwell Reservoir which is under construction on the Ottertail River, and the Red Lakes at the headwaters of the Red Lake River. Other reservoirs in this plan are on the Goose, Forest, Park, Tongue, and Pembina Rivers. Homme Dam on the Park River has been completed, those on the Tongue and Pembina Rivers have been authorized for construction, and those on the Goose and Forest Rivers have been eliminated because they lack economic justification. None of these latter reservoirs by itself has sufficient capacity to satisfy the water needs of the main stem. The Corps of Engineers completed in 1941 an improvement in Lake Traverse, the headwaters of the Bois de Sioux River, for flood control and conservation. The reservoir thus created could make possible small releases of water during periods of dire need, however its effect on Red River low flows would be of minor consequence. Baldhill Dam and Lake Ashtabula, the reservoir created by the dam, located on the Sheyenne River about 16 miles above Valley City, North Dakota, have been recently completed by the Corps of Engineers. Of the useful capacity of 69,500 acre-feet, 18,000 acre-feet is reserved for flood control at the time of spring breakup. This reservoir with proper control could augment the surface waters in the Sheyenne River from the dam to the mouth and in the Fargo-Moorhead area by diverting water from the Sheyenne to the Red River at a point above Fargo. Orwell Dam and Reservoir is located on the Ottertail River 38 miles upstream from the confluence of the Ottertail and Bois de Sioux Rivers. Despite its relatively small useful capacity of 13,100 acre-feet, this reservoir could provide a large quantity of water by virtue of its location on a stream having proportionately greater runoff than other Red River tributaries. It is planned that the entire reservoir would be made available for flood control each spring, and, if needed, a portion of its capacity would be made available for flood control during open-water months.

The Upper and Lower Red Lakes have tremendous storage capacity and an improvement of the dam at their outlet is included in the approved flood-control and water-conservation project on the Red Lake and Clearwater Rivers.

Coordinated operation of Baldhill, Orwell, and Red Lake Reservoirs would do much to alleviate a probable future surface water shortage in the Red River. However, to assure municipalities, industries, and other surface water users an adequate supply for drinking and stream sanitation during an extended drought, additional water will be necessary. The only available means for relieving the surface water deficiency appears to be diversion from the Missouri River.

The Bureau of Reclamation plan, which is coordinated with Corps of Engineers proposals, is based upon collecting return flows from irrigation in the Souris River region and/or pumping from Garrison Reservoir for storage in the Sheyenne Reservoir in the upper reaches of the Sheyenne River. From this reservoir water would be diverted by gravity to restore Devils and Stump Lakes for irrigation, water supply, and pollution abatement along the James River; and for water supply and pollution abatement along the Sheyenne and Red Rivers.

An alternate plan contemplates pumping water from Garrison Reservoir to the headwaters of the Sheyenne and James Rivers. Devils Lake would be restored by pumping from the Sheyenne River and storage for downstream needs on the James, Sheyenne, and Red Rivers would be provided by a reservoir near Jamestown, North Dakota, on the James River, and by the Baldhill Reservoir on the Sheyenne River.

PRESENTATION OF DATA

Municipal Water Supplies

Surface water sources supply the needs of 16 municipalities (table R-4). A total population of 103,430 is served with an average of 10.738 M.G.D. All supplies are coagulated, filtered, settled, and chlorinated. In addition, water is softened at Fergus Falls, Breckenridge, East Grand Forks, Stephen, and Hallock, Minnesota; and Fargo, Grand Forks, Drayton, and Pembina, North Dakota. Wahpeton, Fargo, Mayville, Grand Forks, Drayton, Langdon, and Pembina, North Dakota, and Crookston, Minnesota, practice taste and odor control.

Ground water serves 60 communities in Minnesota, 4 in North Dakota, and 2 in South Dakota (table R-5). These communities with a total population of 79,710 use an average of 5.181 M.G.D., or about 65 gallons per capita per day. The majority of the communities distribute water without treatment. Seven provide coagulation, settling and filtration; 8 chlorinate; 9 soften; 8 remove iron and manganese; and 2 add fluorine for dental caries prophylaxis.

Industrial Water Supplies

Many industrial establishments obtain their water supplies from municipal systems. Others derive all or parts of their needs from individual surface or ground sources. Table R-6 lists seven plants that utilize surface sources to the extent of 12.136 M.G.D. Heavy seasonal demands account for a large portion of the total: beet sugar refining operations during late fall and early winter,10.82 M.G.D.; and potato washers generally from late fall to early spring, 0.2 M.G.D. The water may be treated according to plant needs. Two power plants in Grand Forks use the Red River primarily for cooling water to the extent of about 40 M.G.D.

Those industries utilizing ground water sources are listed in table R-7. In Minnesota 68 plants use 1.630 M.G.D., and in North Dakota 32 plants use 0.427 M.G.D.

Table R-4. Red River Sub-Basin - Municipal surface water supplies

Stream and municipality	State	Miles upstream		Treatment[1]	Population served	Average[7] consumption M.G.D.
		Red River International Boundary	Tributary			
Red River of the North						
Ottertail River		393.7				
Fergus Falls	Minn.		50.0	FHD	10,850	0.705
Breckenridge	Minn.		0.5	AFHD	2,750	0.180
Wahpeton[5]	N.D.		0.5	FTD	2,500	0.205
Fargo[2]	N.D.	298		AFHTD	37,000	4.770
Sheyenne River		273.3				
West Fargo[6]	N.D.		26.0	(6)	150	0.010
Goose River		202.7				
Mayville	N.D.		59.6	FTD	1,650	0.100
Red Lake River		143.0				
Thief River Falls	Minn.		125.3	FD	6,020	0.400
Crookston	Minn.		52.1	FDT	7,300	0.400
East Grand Forks	Minn.		0.5	AFHD	3,510	1.000
Grand Forks[3]	N.D.		0.5	AFHTD	26,000	2.600
Tamarack River		64.6				
Stephen	Minn.		14.0	AFHD	400	0.030
Drayton	N.D.	53.2		FHTD	850	0.040
Two Rivers		20.2				
Middle Fork			14.0			
Hallock	Minn.		12.0	AFHD	1,350	0.088
Pembina River		2.8				
Mulberry Creek			78.0			
Langdon[4]	N.D.		36.0	FTD	1,500	0.060
Tongue River			8.8			
Cavalier[2]	N.D.		29.0	FD	1,100	0.100
Pembina	N.D.		0.5	FHTD	500	0.050
Totals					103,430	10.738

[1] Treatment - A - Aeration.
D - Chlorination.
F - Coagulation, sedimentation, filtration.
H - Softening.
T - Taste and odor control.

[2] Wells are used as standby units.

[3] Grand Forks obtains its water in varying proportions from Red and Red Lake Rivers, usually in a ratio of 1:1.

[4] Langdon has constructed a reservoir in Mulberry Creek to catch spring runoff. Water is piped from the reservoir to an artificial infiltration gallery.

[5] Wells supplement surface supply - approximately one-half of the municipal supply is taken from the river, the other half of the consumption is included in the ground water supply table.

[6] West Fargo obtains water supply from the Armour & Co. meat packing plant. Treatment FHD.

[7] State Health Department Records.

Table B-5. Red River Sub-Basin - Municipal ground water supplies

Municipality	State	Source[1]	Treatment[2]	Population served	Average consumption M.G.D.
Ada	Minn.	W	N	1,500	0.070
Argyle	Minn.	W	N	420	0.120
Bagley	Minn.	W	N	420	0.035
Barnesville	Minn.	W	DI	1,450	0.090
Battle Lake	Minn.	W	N	460	0.020
Battle Lake Ottertail County Sanatorium[7]	Minn.	W	N	50	0.002
Bejou	Minn.	W	N	170	0.010
Blackduck	Minn.	W	FH	420	0.025
Callaway	Minn.	W	N	90	0.006
Campbell	Minn.	W	N	300	0.004
Clearbrook	Minn.	W	N	530	0.025
Crookston-Sunnyrest San.[7]	Minn.	W	FH	80	0.003
Detroit Lakes	Minn.	W	AD	5,020	0.300
Dilworth	Minn.	W	N	700	0.033
Donnelly	Minn.	W	N	180	0.003
Dumont	Minn.	W	N	210	0.006
Elbow Lake	Minn.	W	N	1,150	0.060
Erskine	Minn.	W	N	400	0.030
Fertile	Minn.	W	N	800	0.048
Fisher	Minn.	W	N	300	0.015
Fosston	Minn.	W	N	1,270	0.050
Frazee	Minn.	W	N	330	0.035
Gonvick	Minn.	W	N	370	0.020
Graceville	Minn.	W	AFI	750	0.100
Greenbush	Minn.	W	N	180	0.015
Halstad	Minn.	W	N	670	0.044
Hawley	Minn.	W	N	810	0.025
Hendrum	Minn.	W	N	220	0.014
Herman	Minn.	W	N	130	0.010
Karlstad	Minn.	W	N	200	0.010
Kelliher	Minn.	W	N	240	0.150
Kennedy	Minn.	W	D	340	0.002
Kent	Minn.	W	N	170	0.010
Lake Park	Minn.	W	N[3]	650	0.040
McIntosh	Minn.	W	N	380	0.020
Mahnomen	Minn.	W	N	1,050	0.043
Moorhead	Minn.	W	DFH	9,400	0 500
New York Mills	Minn.	W	AIH	450	0.029
Nielsville	Minn.	W	N	180	0.010
Northome	Minn.	W	N	90	0.006
Oklee	Minn.	W	N	400	0.030
Pelican Rapids	Minn.	W	N	740	0.048
Perham	Minn.	W	N	740	0.075
Perley	Minn.	W	N	180	0.012
Plummer	Minn.	W	N	280	0.013
Puposky, Lake Julia San.[7]	Minn.	W	H	60	0.003
Red Lake Falls	Minn.	W	BHI	1,500	0.100
Red Lake Indian Agency	Minn.	W	I	300	0.015
Roseau	Minn.	W	N	1,220	0.135
Rothsay	Minn.	W	N	230	0.025
Shelly	Minn.	W	N	340	0.022
Thief River Falls, Oakland Park San.[7]	Minn.	W	H	60	0.003
Twin Valley	Minn.	W	N	540	0.014
Ulen	Minn.	W	N	390	0.007
Underwood	Minn.	W	N	270	0.030
Warren	Minn.	W	N	1,640	0.090
Wendell	Minn.	W	N	170	0.035
Wheaton	Minn.	W	N	1,660	0.105
Winger	Minn.	W	N	300	0.015
Wolverton	Minn.	W	N	210	0.013
Subtotal				43,760	2.828
Abercorombie	N.Dak.	W	N	240	0.005
Amenia	N.Dak.	W	N	130	0.001
Anamoose	N.Dak.	W	N	500	0.020
Casselton	N.Dak.	W	N	950	0.040
Cooperstown	N.Dak.	W	I	800	0.025
Elliot	N.Dak.	W	N	80	0.005
Enderlin	N.Dak.	W	FH	1,500	0.080
Fairmount	N.Dak.	W	N	650	0.072
Finley	N.Dak.	W	N	640	0.017
Forman	N.Dak.	W	N	480	0.030
Goodrich	N.Dak.	W.	N	350	0.020
Grafton	N.Dak.	W	N	4,000	0.260
Gwinner	N.Dak.	W	N	250	0.003
Hankinson	N.Dak.	W	N	1,200	0.044
Harvey	N.Dak.	W	ADFI	1,800	0.150
Hatton	N.Dak.	W	N	700	0.013
Hillsboro	N.Dak.	W	N	1,300	0.075
Kathryn	N.Dak.	S	N	200	0.013
Larimore	N.Dak.	W	N	1,200	0.085
Lidgerwood	N.Dak.	W	N	1,100	0.080
Lisbon	N.Dak.	W	AFHI	1,600	0.100
McClusky	N.Dak.	W	N	600	0.040
McVille	N.Dak.	W	N	500	0.035
Maddock	N.Dak.	W	N	600	0.095
Minto	N.Dak.	W	D	300	0.004
Mooreton	N.Dak.	W	N	130	0.008
Mountain	N.Dak.	W	N	220	0.003
Northwood	N.Dak.	W	B	700	0.040
Park River	N.Dak.	W[4]	D	1,500	0.090
Sheldon	N.Dak.	W	N	200	0.010
Southwest Fargo	N.Dak.	W	N	930	0.040
Valley City	N.Dak.	W[5]	D	6,700	0.550
Wahpeton	N.Dak.	W[6]	N	2,500	0.205
Walhalla	N.Dak.	W	N	900	0.075
Subtotal				35,450	2.333
Newark	S.Dak.	W	N	20	---[8]
Veblen	S.Dak.	S	N	480	0.020
Subtotal				500	0.020
Total				79,710	5.181

[1] Source - W - Wells
S - Springs

[2] Treatment - A - Aerated
B - Fluoridation
D - Chlorinated
F - Coagulated, settled, and filtered
H - Softened
I - Iron or manganese removal
N - None

[3] Phosphate added for water stablization.

[4] Well is naturally recharged by infiltration from Park River.

[5] Artificial recharge - gravity diversion from Sheyenne River.

[6] Wells supplement surface supply - approximately one-half of city supply is taken from wells, other half of consumption is included in the surface supply table.

[7] Sanatorium.

[8] Newark has a private system serving 20 persons an estimated 250 gallons per day.

Table R-6. Red River Sub-Basin - Industrial surface water supplies

Stream and industry	Location	Miles upstream: Red River International Boundary	Miles upstream: Tributary	Average consumption gals. per day
Red River of the North				
Amer.Crystal Sugar Co.	Moorhead, Minn.	293.5		5,320,000[a]
Sheyenne River		272.3		
Russel Miller Milling Co.	Valley City, N.D.		253.4	116,000
Armour & Co.	West Fargo, N.D.		26.0	1,000,000
Red Lake River		143		
Potato Products Corp.	E.Grand Forks,Minn.		2.0	40,000
Amer.Crystal Sugar Co.	E.Grand Forks,Minn.		2.0	5,500,000[a]
Northern States Power Co.	Grand Forks, N.D.	142.9		(d)
Minnkota Power Co-Op.	Grand Forks, N.D.	141.1		(d)
Pembina River		2.8		
M.C.Rutherford Potato Washer	Walhalla, N.D.		87.6	150,000[b]
Tongue River			6.0	
Harris & Robbie Potato Washer	Cavalier, N.D.		27.0	10,000[c]
Total				12,136,000

[a] Seasonal use.

[b] River water until it is frozen then uses municipal water.

[c] Use both river and well water.

[d] Primarily cooling water - Northern States Power Co. uses 13.72 M.G.D. and Minnkota Power Co-Op. uses 26.42 M.G.D.

Pollution Contributed to Water Resources

Municipal

The location and magnitude of municipal sources of pollution, including industries connected to municipal sewerage, are summarized in table R-8. Listed are 90 sources of pollution serving a total population of 189,200. Industrial wastes contribute a population equivalent of 75,920 to municipal sewer systems for a total untreated population equivalent of 265,120. Treatment reduces the strength of the waste slightly over 50 percent to a discharge with a population equivalent of 131,460, of which a population equivalent of 11,880 is in landlocked areas and normally does not reach flowing water courses.

Twenty-two municipalities do not have community treatment plants although two require passage of wastes through septic tanks prior to discharge to sewers. This latter practice developed through individuals wasting septic tank effluent to storm drains. Municipal septic tank installations which at best provide only minor treatment are found in nine instances. Sewage from 29 communities is given primary treatment and that from 34 communities secondary treatment. Seventy-five percent of sewered municipalities provide treatment as compared to a national average of about 61 percent. Deleting those with septic tanks, about 65 percent of sewered communities use satisfactory treatment methods.

Table R-7. Red River Sub-Basin - Industrial ground water supplies

Industry	Location	Estimated average consumption gallons per day
Minnesota		
Ada Co-op. Cry. Assn.	Ada	7,200
Audubon Co-op. Cry. Assn.	Audubon	12,000
Bagley Co-op. Cry. Co.	Bagley	16,200
Battle Lake Co-op. Cry.	Battle Lake	36,000
Beltrami Co-op. Cry. Assn.	Beltrami	5,000
Big "5" Co-op. Assn.	Audubon	-
Community Cry.	Lake Bronson	-
Dent Co-op. Cry. Assn.	Dent	42,000
Detroit Co-op. Dairy Assn.[a]	Detroit Lakes	8,400
Elizabeth Cry. Assn.	Elizabeth	2,500
Falls Brewery[a]	Fergus Falls	-
Farmers Co-op. Cry. Assn.	Erhard	-
Farmers Co-on. Cry. Assn.	Goodridge	-
Farmers Co-op. Cry. Assn.	Newfolden	-
Farmers Co-op. Cry. Assn.	Viking	6,000
Farmers Cry. Co.	Halma	9,000
Fergus Falls Co-op. Cry. Assn.	Fergus Falls	2,500
Flom Co-op. Cry. Assn.	Flom	10,000
Fosston Farmers Co-op. Assn.	Fosston	-
Gary Cry. Assn.	Gary	-
Gerners Cry.	Hitterdal	9,000
Gonvick Co-op. Cry. Assn.	Gonvick	60,000
Grygla Co-op. Cry. Assn.	Grygla	20,000
Gully Farmers Co-op. Cry.	Gully	-
Hawley Cry. Assn.	Hawley	120,000
Holt Co-op. Cry. Assn.	Holt	-
Karlstad Co-op. Cry. Assn.	Karlstad	10,800
Lakes Dairy Co-op.	Detroit Lakes	320,000
Lake Park Co-op. Cry. Co.	Lake Park	12,000
Lancaster Co-op. Cry. Assn.	Lancaster	4,000
Lancaster Co-op. Locker	LAncaster	-
Land O'Lakes	Ada	90,000
Land O'Lakes Dairy Assn.	Fosston	180,000
Land O'Lakes Cry. Assn.	Perham	-
Lengby Co-op. Cry. Assn.	Lengby	7,200
Leonard Co-op. Cry. Assn.	Leonard	10,800
McIntosh Coop. Cry. Assn.	McIntosh	18,000
Mahnomen Co-op. Cry. Assn.	Mahnomen	15,000
Marshal County Co-op. Locker	Newfolden	-
Mentor Cry. Assn.	Mentor	-
Middle River City Co-op. Cry.	Middle River	-
Nashua Coop. Cry. Assn.	Nashua	14,400
New York Mills Co-op. Assn.[a]	New York Mills	-
Norcross Co-op. Cry. Assn.	Norcross	1,000
North Star Cry. Assn.	Badger	14,400
North Star Dairy	Fergus Falls	250,000
Ogema Creamery	Ogema	-
Oklee Coop. Assn.	Oklee	-
Ottertail Co-op. Cry. Assn.	Ottertail	36,000
Perham Coop. Cry. Assn.[a]	Perham	144,000
Perley Co-op. Cry. Assn.	Perley	3,600
Plummer Co-op. Cry. Assn.	Plummer	-
Rindal Co-op. Dairy Assn.	Rindal	-
Rollis Co-op. Cry. Assn.	Gatzke	-
Ross Co-op. Cry. Assn.	Ross	-
St. Hilaire Co-op. Cry. Assn.	St. Hilaire	-
Strandquist Cry. Co.	Strandquist	4,000
Sundahl Co-op. Cry. Assn.	Sundahl	-
Thief River Falls Co-op.	Thief River Falls	-
Trail Co-op. Cry.	Trail	-
Twin Valley Co-op. Cry. Assn.	Twin Valley	-
Underwood Co-op. Cry. Co.	Underwood	-
Vergas Cry. Co.	Vergas	18,000
Vining Co-op. Cry. Assn.	Vining	94,000
Wannaske Cry. Assn.	Wannaske	-
Waubun Creamery	Waubun	-
Wolf Lake Co-op. Cry. Assn.	Wolf Lake	17,000
Wolf Lake Lockers	Wolf Lake	-
Subtotal		1,630,000
North Dakota		
Aasand Potato Co.	Grafton	12,000
Aneta Creamery and Produce	Aneta	2,000
Armour & Co.	Grand Forks	100,000
Associated Potato Growers	Grand Forks	25,000
Baldwin Potato Co.	St. Thomas	25,000
Bridgeman Creameries, Inc.	Grand Forks	50,000
Drayton Creamery	Drayton	1,500
Edinburg Creamery	Edinburg	2,000
Fargo Packing	S.W. Fargo	1,500
F. U. Co-op. Creamery	Portland	4,500
Farmers Union Locker	Aneta	1,000
Folson-Kennedy Potato Washer	St. Thomas	80,000
Fordville Creamery	Fordville	5,000
Golden Valley Creamery	Park River	4,000
Grafton Locker Plant	Grafton	1,000
Halverson Bros. Locker Plant	Northwood	2,500
Harris & Robbie Potato Washer	Cavalier	10,000
Hoople Seed Potato Co.	Hoople	25,000
Hunter Creamery	Hunter	1,000
J. G. Hall & Sons Potatoes	Edinburg	2,000
Larimore Creamery	Larimore	1,500
McVille Creamery	McVille	3,000
Meat Service Co.	Grand Forks	5,000
Michigan Creamery	Michigan City	1,000
Petersburg Co-op. Creamery	Petersburg	3,000
Potato Packers, Inc.	Grand Forks	25,000
Spencer Creamery	Manvel	1,500
Stangler's Market	Alice	1,000
Tony's Market	Mayville	1,500
Valley City Rendering	Valley City	25,000
Wyndmere Creamery	Wyndmere	3,500
Wyndmere Locker Plant	Wyndmere	1,000
Subtotal		427,000
Grand Total		2,057,000

---

[a] Uses both municipal and private well water.

[b] Uses both river and well water.

Table R-8. Red River Sub-Basin - Basic data on sources of municipal pollution

Stream and Municipality	Miles upstream		Population served by sewers	Population equivalent (B.O.D.) untreated waste[1]	Waste treatment provided	Adequacy of treatment facilities		Population equivalent discharged to watercourse[1]	Project needs	Current status municipal action
	Red River International Boundary	Tributary				Cap'y	Oper.			
Red River of the North										
Bois de Sioux River	393.7									
Mustinka River		41.7								
Elbow Lake, Minn.		48.0	1,300	1,380	Primary	Unsat.	Unsat.	960	Addition	Inactive
Five Mile Creek		17.2								
Herman, Minn.		17.0	620	780	None	-	-	780	New plant	Inactive
Twelve Mile Creek		16.6								
Donnelly, Minn.		38.0	240	780	None	-	-	780	New plant	Inactive
West Branch		11.5								
Graceville, Minn.		23.0	770	790	Primary	Unsat.	Unsat.	550	Addition	Inactive
Cottonwood Slough		32.0								
Rosholt, S. D.		5.0	300	300	Primary	Sat.	Sat.	(220)[c]	None	-
Fairmount, N.D.		17.5	620	2,080	None	-	-	2,080	New plant	Inactive
Ottertail River	393.7									
Frazee, Minn.		147.4	720	2,520	Primary	Unsat.	Unsat.	1,760	Addition	Inactive
Perham, Minn.		127.0	1,890	3,600	Secondary	Sat.	Sat.	1,080	None	-
Drainage Ditch		110								
New York Mills, Minn.		4	870	1,520	Secondary	Sat.	Unsat.	460	None	-
Battle Lake, Minn.		91.0	(560)[g]	-	(Sec.)[g]	-	-	-	-	Under construction
Ottertail Sanitarium, Minn.		52.0	40	40	Primary	Sat.	Sat.	30	None	-
Fergus Falls, Minn.		50.0	14,750	20,730	Primary	Unsat.	Unsat.	13,100	Addition	Active planning
Pelican River		45.8								
Detroit Lakes, Minn.		53.0	5,060	8,420	Secondary	Sat.	Sat.	1,770	None	-
Pelican Rapids, Minn.		23.0	1,600	3,040	Secondary	Sat.	Unsat.	910	None	-
Breckenridge, Minn.	392.0		2,450	3,100	None	-	-	3,100	New plant	Active planning
Wahpeton, N.D.	392.0		4,000	4,240	Secondary	Sat.	Sat.	1,200	None	-
Abercrombie, N.D.	377.0		200	440	None[d]	Sat.	Unsat.	370	None	-
Wolverton, Minn.	348.0		300	360	Primary	Unsat.	Sat.	250	Addition	Inactive
Wild Rice River	315.2									
Veblen, S.D.		125	380	540	Primary	Unsat.	Sat.	(380)[b]	Addition	Inactive
Forman, N. D.		115	400	400	Minor[a]	Unsat.	Unsat.	(280)[c]	New plant	Inactive
Milnor, N.D		112	700	700	Primary	Sat.	Sat.	(460)[b]	None	-
Lidgerwood, N.D.		109	1,100	1,100	Minor[a]	Unsat.	Unsat.	(1,000)[c]	New plant	Inactive
Hankinson, N.D.		72	1,050	1,660	Minor[a]	Unsat.	Sat.	(1,400)[b]	New plant	Inactive
Moorhead, Minn.	292.2		14,060	20,240	Secondary	Sat.	Sat.	3,040	None	-
Dilworth, Minn.	292.2		1,280	1,280	Secondary[f]	-	-	f	-	-
Fargo, N.D.	286.2		35,000	43,700	Secondary	Unsat.	Sat.	10,330	Enlargement	Inactive
Sheyenne River	273.3									
McClusky, N.D.		568	500	500	Primary	Sat.	Sat.	(320)[c]	None	-
Goodrich, N.D.		557	350	350	Primary	Sat.	Sat.	(230)[b]	None	-
Anamoose, N.D.		518	500	900	None	-	-	(900)[c]	New plant	Inactive
Harvey, N.D.		462	2,000	2,500	None	-	-	2,500	New plant	Inactive
Maddock, N.D.		428	600	1,650	Lagoon	Sat.	Sat.	e	None	-
McVille, N.D.		348	500	800	Minor[a]	Unsat.	Sat.	(700)[b]	New plant	Inactive
Cooperstown, N.D.		324.7	800	1,060	Minor[a]	Unsat.	Sat.	(830)[b]	New plant	Inactive
Baldhill Creek		276								
Wimbledon, N.D.		29	350	600	Minor[a]	Unsat.	Sat.	(500)[c]	New plant	Inactive
Valley City, N.D.		253.4	6,100	8,570	Secondary	Sat.	Unsat.	3,000	None	-
Lisbon, N.D.		162.1	1,500	1,680	Secondary	Sat.	Sat.	600	None	-
N.D.State Old Soldiers Home		158.0	200	200	Secondary	Sat.	Sat.	60	None	-
Kindred, N.D.		68.1	(500)[g]	-	(Sec.)[g]	-	-	-	-	Under construction
Southwest Fargo, N.D.		26.0	920	1,000	Secondary	Sat.	Sat.	300	None	-
West Fargo, N.D.		26.0	150	150	Secondary[h]	-	-	h	-	-
Maple River		19.8								
Enderlin, N.D.		52.0	1,400	1,400	Minor[a]	Unsat.	Sat.	1,200	New plant	Inactive
Swan Creek		20.9								
Casselton, N.D.		9.0	950	1,800	Minor[a]	Unsat.	Unsat.	(1,620)[b]	New plant	Inactive
Rush River		11.5								
Amenia, N.D.		26.7	120	120	None[d]	Sat.	Unsat.	(100)[b]	None	-
Buffalo River	262.5									
Callaway, Minn.		72.0	190	280	Primary	Unsat.	Sat.	190	Addition	Inactive
Sand Beach Sanitarium, Minn.		56.0	80	80	Secondary	Sat.	Sat.	20	None	-
Lake Park, Minn.		56.0	580	1,030	Secondary	Sat.	Sat.	260	None	-
Hawley, Minn.		43.4	1,400	2,980	None	-	-	2,980	New plant	Inactive
South Branch		22.0								
Deerhorn Creek		19.0								
Rothsay, Minn.		26.0	360	460	Secondary	Sat.	Sat.	90	None	-
Willow Creek		19.0								
Barnesville, Minn.		12.0	1,800	1,880	Secondary	Sat.	Unsat.	560	None	-
Minnesota Wild Rice River	225.4									
Mahnomen, Minn.		106.0	1,430	1,620	None	-	-	1,620	New plant	Inactive
Twin Valley, Minn.		69.0	730	830	None	-	-	830	New plant	Inactive
South Branch		21.0								
Ulen, Minn.		23.0	270	870	Secondary	Sat.	Sat.	130	None	-
Halstad, Minn.	220.4		500	720	None	-	-	720	New plant	Inactive
Goose River	202.7									
Northwood, N.D.		161	700	810	Primary	Unsat.	Sat.	(600)[c]	Addition	Inactive
South Branches		84								
Finley, N.D.		41	640	940	Primary	Unsat.	Sat.	(670)[c]	Addition	Inactive
Hope, N.D.		37	(350)[g]	-	(Lagoon)[g]	-	-	e	-	Under construction
Portland, N.D.		79.1	100	800	Lagoon	Unsat.	Sat.	e	New plant	Under construction
Mayville, N.D.		59.6	1,500	2,000	Primary	Unsat.	Unsat.	1,700	New plant	Inactive
North Branch		45.7								
Hatton, N.D.		23.0	450	750	Primary	Sat.	Sat.	(500)[b]	None	-
Hillsboro, N.D.		28.2	1,300	2,640	None	-	-	2,640	New plant	Inactive
Marsh River	201.7									
Ada, Minn		39.4	1,510	2,880	Primary	Unsat.	Unsat.	2,450	Replacement	Under construction

Table R-5. Red River Sub-Basin - Basic data on sources of municipal pollution (Cont'd)

Stream and Municipality	Miles upstream		Population served by sewers	Population equivalent (B.O.D.) untreated waste[1]	Waste treatment provided	Adequacy of treatment facilities		Population equivalent discharged to watercourse[1]	Project needs	Current status municipal action
	Red River International Boundary	Tributary				Cap'y	Oper.			
Red River of the North										
Sandhill River	187.0									
Fertile, Minn.		36.0	810	2,900	None	-	-	2,900	New plant	Inactive
Climax, Minn.		1.5	100	100	None	-	-	100	New plant	Inactive
Red Lake River	143.0									
Battle River		195								
Northome, Minn.		41	140	200	Primary	Unsat.	Sat.	140	Replacement	Inactive
Kelliher, Minn		33	180	240	Primary	Unsat.	Unsat.	170	Addition	Inactive
Blackduck River		195								
Blackduck, Minn.		27	890	1,020	Primary	Unsat.	Unsat.	710	Replacement	Final plans approved
Thief River		130								
Mud River		22								
Lake Julia Sanitorium, Minn.			60	60	Secondary	Sat.	Sat.	20	None	-
Red Lake Indian Agency, Minn.			300	300	Secondary	Sat.	Sat.	80	None	-
Thief River Falls, Minn.		125.3	6,920	17,270	Secondary	Sat.	Sat.	2,590	None	-
Oakland Park Sanitorium, Minn.			60	60	Secondary	Sat.	Sat.	20	None	-
Clearwater River		91.2								
Bagley, Minn.		103.0	1,380	1,600	Secondary	Sat.	Sat.	320	None	-
Clearbrook, Minn.		81.0	(430)[g]	-	(Sec.)[g]	-	-	-	-	Under construction
Poplar River		20.6								
Fosston, Minn.		33.0	1,310	2,490	Secondary	Sat.	Sat.	620	None	-
McIntosh, Minn.		22.0	880	1,010	Secondary	Sat.	Sat.	300	None	-
Red Lake Falls, Minn.		2.3	1,670	1,790	Primary	Unsat.	Unsat.	1,260	Enlargement	Final plans approved
Crookston, Minn.		52.1	6,530	7,500	None	-	-	7,500	New plant	Final plans approved
Sunnyrest Sanatorium, Minn.			80	80	None	-	-	80	New plant	Inactive
East Grand Forks, Minn.	142		5,040	6,280	None	-	-	6,280	New plant	Final plans approved
Grand Forks, N.D.	140.5		25,000	29,850	Primary	Unsat.	Sat.	18,000	Addition	Inactive
Turtle River	118.6									
Michigan City, N.D.		59.0	400	820	Lagoon	Sat.	Sat.	[e]	None	-
Larimore, N.D.		39.0	1,230	3,320	Primary	Unsat.	Unsat.	2,800	New plant	Final plans approved
Snake River	75.2									
Warren, Minn.		38.0	1,270	1,590	Primary	Unsat.	Unsat.	1,110	Replacement	Active planning
Middle River		6.0								
Argyle, Minn.		15.0	840	1,050	None	-	-	1,050	New plant	Active planning
Park River	67.3									
Park River, N.D.		41.0	1,400	1,600	Primary	Unsat.	Unsat.	1,440	Replacement	Inactive
Grafton, N.D.		30.4	3,700	4,500	Secondary	Sat.	Sat.	1,100	None	-
Tamarack River	64.6									
Stephen, Minn.		16.0	760	1,080	Primary	Sat.	Unsat.	860	Addition	Inactive
Drayton, N.D.	53.2		850	950	None	-	-	950	New plant	Final plans approved
Nameless Creek	32.0									
Kennedy, Minn.		18.0	190	290	None	-	-	290	New plant	Inactive
Two Rivers	20.2									
Middle Fork		14.0								
Hallock, Minn.		12.0	1,160	1,790	Primary	Unsat.	Unsat.	1,260	Addition	Final plans approved
North Fork		4.0								
Lancaster, Minn.		24.0	160	390	Primary	Unsat.	Unsat.	270	New plant	Inactive
Pembina River	2.8									
Mulberry Creek		76.0								
Langdon, N.D.		26.0	1,500	1,800	Primary	Sat.	Sat.	(1,170)[b]	None	-
Walhalla, N.D.		87.6	900	1,000	None	-	-	1,000	New plant	Inactive
Tongue River		6.0								
Cavalier, N.D.		27.0	1,100	1,200	Minor[a]	Unsat.	Unsat.	1,000	Replacement	Active planning
Roseau River	(j)									
Roseau, Minn.		142.9	2,210	2,400	Secondary	Sat.	Unsat.	960	None	-
Total			189,200	265,120				131,460 (11,880)[i]		

---

[1] Includes organic industrial wastes discharging to municipal systems.

[a] Septic tank.

[b] Discharge to intermittent creek - pollution reaches watercourse only during periods of high water.

[c] Discharge to slough--drainage to watercourse indefinite or not existent and primarily of local significance.

[d] Individual treatment prerequisite to connecting to system.

[e] Discharge to an artificial lagoon--no outlet to watercourse.

[f] Dilworth sewage treated by the Moorhead, Minn., plant.

[g] New system - population served is not included in the column total.

[h] Armour Co. treatment plant

[i] Wastes generally not reaching flowing watercourse.

[j] Discharges in Canada.

Industrial

Basic data on sources of industrial pollution are included in table R-9. Eighty-five industrial establishments, all associated with food processing, produce wastes most of which are organic in nature. The total population equivalent of the waste is 345,230 of which 220,000 is a winter seasonal load from two sugar beet refineries leaving a normal discharge of 125,230 population equivalents. The normal load is reduced 40 percent by treatment to a population equivalent of 74,800. Of the latter total, a population equivalent of 2,280 does not normally reach streams because of local topographical characteristics. Waste from one of the sugar refineries is lagooned and satisfactorily discharged during high spring flows, while waste from the other receives some benefit through sedimentation although the basin to which it is discharged is too small to be effective as a lagoon.

Industrial wastes are discharged without treatment in 28 cases, minor or negligible treatment in 34 instances, primary treatment in 6 places, and secondary or equivalent or better treatment in 17 locations. Thus, treatment of some type is practiced at 57 out of 85 establishments, or at over 67 percent of the industrial plants.

Low Flow Frequencies

A brief study of historic stream discharges was made to indicate the probable frequency of future low flows for summer and winter months (table R-10). The minimum mean monthly flow for these periods for each of the years of record was selected and used as a basis for determinations. Probable low flow frequencies can be used to ascertain the degree of treatment required and to predict the recurrence of odious conditions in the stream.

Stream discharge data reveal that in the past the Red River and its tributaries suffered diminished flows that reached or closely approximated zero for protracted intervals. As a result severe oxygen depressions may occur with concomitant nuisance conditions.

Average stream velocity, without ice cover, between Fargo and Grand Forks varies from about 10 miles per day at a discharge of 50 c.f.s. to about 37 miles per day at 5,000 c.f.s. Under conditions of ice cover, the average stream velocity is about 7 miles per day at a discharge of 50 c.f.s. to approximately 25 miles per day at 5,000 c.f.s.

For the stretch below Grand Forks to the International Boundary, the average velocity without ice cover varies from about 14 miles per day at a flow of 150 c.f.s. to about 42 miles per day at a discharge of 5,000 c.f.s. Under ice coverage the velocity ranges from approximately 9 miles per day at 150 c.f.s. to about 28 miles per day at 5,000 c.f.s.

The slope of the main stem is about 1.3 feet per mile in the upper reaches and approximately 0.2 feet per mile near the International Boundary, an average of 0.5 feet per mile. Channel widths vary from 200 to 500 feet and average depths at bankfull vary from 10 to 30 feet. Channel capacities are estimated from 1,500 to 20,000 second-feet.

Table R-9. Red River Sub-Basin - Basic data on sources of industrial pollution - Industries discharging wastes directly to watercourse

Stream and industry	Miles upstream		Type of industry	Type of waste produced	Population equivalent (B.O.D.) untreated waste	Treatment or other pollution control measure			Population equivalent discharged to watercourse	Pollution abatement needs or equiv. control measures	Current status industrial action
	Red River International Boundary	Tributary				Degree	Adequacy Cap'y	Adequacy Oper.			
Red River of the North											
Bois de Sioux River	393.7										
Mustinka River		41.7									
Norcross Co-op Cream. Assn. Norcross, Minn.		30	Food prod.	Organic	40	Minor[a]	Unsat.	Unsat.	40	New plant	Inactive
Twelve Mile Creek		16.6									
West Branch		11.5									
H.J.Zobach, Dumont, Minn.		10	Food prod.	Organic	280	Minor[a]	Unsat.	Unsat.	280	New plant	Inactive
Rabbit Creek		8									
Ditch		8									
Nashua Co-op Cream. Assn. Nashua, Minn.		2	Food prod.	Organic	290	Minor[a]	Unsat.	Unsat.	290	New plant	Inactive
Creek		4									
The Village Market Campbell, Minn.		1	Food prod.	Organic	180	Minor[a]	Unsat.	Unsat.	180	New plant	Inactive
Ottertail River	393.7										
Frazee Creamery Co. Frazee, Minn.		147.4	Food prod.	Organic	610	None	-	-	610	New plant	Inactive
Slough		140									
Vergas Creamery Co. Vergas, Minn.		5	Food prod.	Organic	170	Minor[a]	Unsat.	Unsat.	(170)[b]	New plant	Inactive
Dent Co-op. Creamery Assn. Dent, Minn.		110	Food prod.	Organic	140	Minor[a]	Unsat.	Unsat.	(140)[b]	New plant	Inactive
Vining Co-op. Creamery Assn. Vining, Minn.		100	Food prod.	Organic	170	None	-	-	170	New plant	Inactive
Pelican River		45.8									
Slough		43									
Farmer Co-op. Creamery Assn. Erhard, Minn.		1	Food prod.	Organic	60	Minor[a]	Unsat.	Unsat.	(60)[b]	New plant	Inactive
Farmers Co-op. Creamery Co. Pelican Rapids, Minn.		23.0	Food prod.	Organic	1,030	None	-	-	1,030	New plant	Inactive
Elizabeth Creamery Assn. Elizabeth, Minn.		7	Food prod.	Organic	80	None	-	-	80	New plant	Inactive
Wild Rice River	315.2										
Wyndmere Locker Co. Wyndmere, N.D.		78.0	Food prod.	Organic	150	Cesspool	Sat.	Sat.	None	None	-
Wyndmere Creamery Wyndmere, N.D.		78.0	Food prod.	Organic	110	None	-	-	(110)[b]	New plant	Inactive
Big Slough Drainage Ditch	285										
Red Owl Warehouse Fargo, N.D.		5	Food prod.	Organic	190	Secondary	Sat.	Unsat.	80	Addition	Active planning
American Crystal Sugar Co. Moorhead, Minn.	293		Food prod.	Organic	126,000	Lagoon	Sat.	Sat.	168,000[c]	None	-
Sheyenne River	273.3										
Aneta Creamery & Produce Aneta, N.D.		320.0	Food prod.	Organic	650	Minor[a]	Unsat.	Unsat.	(550)[e]	New plant	Inactive
Farmers Union Locker Plant Aneta, N.D.		320.0	Food prod.	Organic	120	Minor[a]	Unsat.	Unsat.	(100)[b]	New plant	Inactive
Valley City Rendering Co. Valley City, N.D.		253.4	Food prod.	Organic	1,200	Lagoon	Sat.	Sat.	None	None	-
Olson Meat Mkt., Kindred, N.D.		68.1	Food prod.	Organic	110	Cesspool	Sat.	Sat.	None	None	-
Armour & Co., West Fargo, N.D.		26.0	Food prod.	Organic	42,500	Tertiary	Sat.	Sat.	2,120[f]	None	-
Nameless Creek		25									
Fargo Pack.Co.Slaughter House S.W.Fargo, N.D.		0.5	Food prod.	Organic	150	Primary	Sat.	Sat.	100	None	-
Maple River		19.8									
Stranglers Meat Market Alice, N.D.		78.0	Food prod.	Organic	220	None	-	-	(220)[b]	New plant	Inactive
Buffalo River	262.5										
Creek		27									
Big "S" Co-op Creamery Assn.			Food prod.	Organic	190	Minor[a]	Unsat.	Unsat.	190	New plant	Inactive
Audubon Co-op Creamery Assn. Lake Audubon, Minn.		6	Food prod.	Organic	100	Minor[a]	Unsat.	Unsat.	100	New plant	Inactive
Ditch	245										
Perley Co-op Creamery Assn. Perley, Minn.		1	Food prod.	Organic	50	None	-	-	50	New plant	Inactive
Elm River	227.0										
Hunter Creamery Hunter, N.D.		40.0	Food prod.	Organic	260	None	-	-	260	New plant	Inactive
Minn. Wild Rice River	225.4										
Creek		108									
Ogema Creamery Ogema, Minn.		15	Food prod.	Organic	670	None	-	-	670	New plant	Inactive
Waubun Creamery Waubun, Minn.		8	Food prod.	Organic	130	None	-	-	130	New plant	Inactive
Flom Co-op Creamery Assn. Flom, Minn.		81	Food prod.	Organic	100	Minor[a]	Unsat.	Unsat.	100	New plant	Inactive
Goose River	202.7										
Halverson Bros. Slaughter House Northwood, N.D.		161.0	Food prod.	Organic	530	Cesspool	Sat.	Sat.	None[g]	None	-

Table R-9. Red River Sub-Basin - Basic data on sources of industrial pollution - Industries discharging wastes directly to watercourse (Cont'd)

Stream and industry	Miles upstream Red River International Boundary	Miles upstream Tributary	Type of industry	Type of waste produced	Population equivalent (B.O.D.) untreated waste	Treatment or other pollution control measure: Degree	Adequacy: Cap'y	Adequacy: Oper.	Population equivalent discharged to watercourse	Pollution abatement needs or equiv. control measures	Current status industrial action
Red River of the North											
Goose River (Cont'd)											
South Branches		84									
Sharon Processing Plant, Sharon, N.D.		42	Food prod.	Organic	160	Cesspool	Sat.	Sat.	None	None	-
Hope Locker Plant, Hope, N.D.		37	Food prod.	Organic	100	Cesspool	Sat.	Sat.	None	None	-
North Branch		45.7									
Dean Osking Potato Washing, Hatton, N.D.		13	Food prod.	Inorganic	Not applicable	None	-	-	Not applicable	New plant	Active planning
Marsh River	201.7										
Shelly Farmers Co-op Creamery Shelly, Minn.		2	Food prod.	Organic	150	Minor[a]	Unsat.	Unsat.	150	New plant	Inactive
Sandhill River	187										
Winger Farmers Creamery Co. Winger, Minn.		65	Food prod.	Organic	110	Minor[a]	Unsat.	Unsat.	110	New plant	Inactive
Rindal Co-op Creamery Assn. Rindal, Minn.		50	Food prod.	Organic	220	None	-	-	220	New plant	Inactive
Sundahl Co-op Creamery Assn. Sundahl, Minn.		45	Food prod.	Organic	50	None	-	-	50	New plant	Inactive
Beltrami Co-op Creamery Assn. Beltrami, Minn.		20	Food prod.	Organic	50	None	-	-	50	New plant	Inactive
Red Lake River	143										
Thief River		135									
Moose River		37									
Rollis Co-op Creamery Assn. Gatske, Minn.		6	Food prod.	Organic	60	Minor[a]	Unsat.	Unsat.	60	New plant	Inactive
Mud River		22									
Grygla Co-op Creamery Assn. Grygla, Minn		23	Food prod.	Organic	90	None	-	-	90	New plant	Inactive
Holt Co-op Creamery Assn. Holt, Minn.		15	Food prod.	Organic	100	None	-	-	(100)[b]	New plant	Inactive
Farmers Co-op Creamery Assn. Goodridge, Minn.		4	Food prod.	Organic	90	Minor[a]	Unsat.	Unsat.	90	New plant	Inactive
St. Hilaire Co-op Creamery St. Hilaire, Minn.		110	Food prod.	Organic	170	None	-	-	170	New plant	Inactive
Clearwater River		91.2									
Leonard Co-op Creamery Co. Leonard, Minn.		80	Food prod.	Organic	90	Minor[a]	Unsat.	Unsat.	(90)[b]	New plant	Inactive
Plummer Co-op Creamery Assn. Plummer, Minn.		20	Food prod.	Organic	60	None	-	-	60	New plant	Inactive
Lost River		10									
Gonvick Co-op Creamery Assn. Gonvick, Minn.		30	Food prod.	Organic	100	Minor[a]	Unsat.	Unsat.	100	New plant	Inactive
Gully Farmers Co-op Creamery Gully, Minn.		25	Food prod.	Organic	60	None	-	-	60	New plant	Inactive
Oklee Co-op Assn. Oklee, Minn.		10	Food prod.	Organic	110	None	-	-	(110)[b]	New plant	Inactive
Creek		5									
Erskine Creamery Assn. Erskine, Minn.		15	Food prod.	Organic	120	Minor[a]	Unsat.	Unsat.	120	New plant	Inactive
Creek		4									
Mentor Creamery Assn. Mentor, Minn.		18	Food prod.	Organic	60	Minor[a]	Unsat.	Unsat.	60	New plant	Inactive
Red Lake Falls Rendering Co. Red Lake Falls, Minn.		90	Food prod.	Organic	150	Primary	Unsat.	Unsat.	80	Englarement	Under construction
Fisher Co-op Creamery Assn. Fisher, Minn.		17	Food prod.	Organic	180	None	-	-	180	New plant	Inactive
Potato Products Corp. E. Grand Forks, Minn.	141.2		Food prod.	Organic	26,300	None	-	-	26,300	New plant	Inactive
American Crystal Sugar Co., E. Grand Forks, Minn.	141.2		Food prod.	Organic	94,000	Minor	Unsat.	Unsat.	94,000	New plant	Inactive
Associated Potato Growers Grand Forks, N.D.	140.9		Food prod.	Inorganic	Not applicable	Lagoon	Sat.	Sat.	Not applicable	None	-
N.D. Mill and Elevator Grand Forks, N.D.	140.8		Food prod.	Organic	2,500	None	-	-	2,500	New plant	Inactive
Potato Packers, Inc. Grand Forks, N.D.	140.7		Food prod.	Inorganic	Not applicable	Primary	Sat.	Sat.	Not applicable	None	-
Rogers Bros. Seed Co., Food Products Division Grand Forks, N.D.	140.6		Food prod.	Organic	6,700	Primary	Unsat.	Sat.	5,700	Addition	Inactive
Armour & Co. Grand Forks, N.D.	140.2		Food prod.	Organic	32,100	Minor[a]	Unsat.	Unsat.	27,300	New plant	Inactive
English Coulee	138.0										
Meat Service Co. Grand Forks, N.D.		3	Food prod.	Organic	600	Minor[a]	Unsat.	Unsat.	520	New plant	Inactive
Turtle River	118.6										
Petersburg Co-op Creamery Petersburg, N.D.		67	Food prod.	Organic	500	Minor[a]	Sat.	Sat.	(400)[b]	None	-

Table R-9. Red River Sub-Basin - Basic data on sources of industrial pollution - Industries discharging wastes directly to watercourse (Cont'd)

Stream and industry	Miles upstream Red River International Boundary	Miles upstream Tributary	Type of industry	Type of waste produced	Population equivalent (B.O.D.) untreated waste	Treatment or other pollution control measure Degree	Adequacy Cap'y	Adequacy Oper.	Population equivalent discharged to watercourse	Pollution abatement needs or equiv. control measures	Current status industrial action
Red River of the North											
Turtle River (Cont'd)											
Spencer Creamery Co. Manvel, N.D.		25	Food prod.	Organic	230	None	-	-	230	New plant	Inactive
Forest River	86										
Fordville Creamery Fordville, N.D.		78	Food prod.	Organic	230	Cesspool	Unsat.	Unsat.	(230)[b]	New plant	Inactive
Minto Locker Co. Minto, N.D.		21	Food prod.	Organic	220	Cesspool	Sat.	Sat.	None	None	-
Snake River	75.2										
Farmers Co-op Creamery Assn. Viking, Minn.		55	Food prod.	Organic	80	Minor[a]	Unsat.	Unsat.	80	New plant	Inactive
Middle River		6									
Middle River City Co-op Creamery Middle River, Minn.		65	Food prod.	Organic	110	None	-	-	110	New plant	Inactive
Farmers Co-op Creamery Assn. Newfolden, Minn.		50	Food prod.	Organic	100	None	-	-	100	New plant	Inactive
Park River	67.3										
Edinburg Creamery Edinburg, N.D.		71.0	Food prod.	Organic	230	Cesspool[b]	Sat.	Sat.	None	None	-
J.G.Hall Sons Potatoes Edinburg, N.D.		71.0	Food prod.	Inorganic	Not applicable	[g]	Sat.	Sat.	None	None	-
Hoople Seed Potato Co. Hoople, N.D.		48.0	Food prod.	Inorganic	Not applicable	Primary	Sat.	Sat.	None[g]	None	-
Aasand Potato Co. Grafton, N.D.		30.4	Food prod.	Inorganic	Not applicable	Minor[a]	Sat.	Sat.	None[g]	None	-
Gillespie Meat Market Grafton, N.D.		30.4	Food prod.	Organic	520	Cesspool[g]	Sat.	Sat.	None	None	-
Grafton Locker Co. Grafton, N.D.		30.4	Food prod.	Organic	400	Cesspool[g]	Sat.	Sat.	None	None	-
Tamarack River	64.6										
Creek		50									
Standquist Creamery Co. Standquist, Minn		5	Food prod.	Organic	100	Minor[a]	Unsat.	Unsat.	100	New plant	Inactive
Drayton Creamery Co. Drayton, N.D.	53.2		Food prod.	Organic	640	Minor[a]	Unsat.	Unsat.	540	New plant	Inactive
Two Rivers	20.2										
South Fork		23									
Farmers Co-op Creamery Assn. Greenbush, Minn.		60	Food prod.	Organic	120	Minor[a]	Unsat.	Unsat.	120	New plant	Inactive
Karlstad Co-op Creamery Karlstad, Minn.		26	Food prod.	Organic	40	Minor[a]	Unsat.	Unsat.	40	New plant	Inactive
Farmers Co-op Creamery Halma, Minn.		20	Food prod.	Organic	60	None	-	-	60	New plant	Inactive
Community Creamery Lake Bronson, Minn.		17	Food prod.	Organic	100	Minor[a]	Unsat.	Unsat.	100	New plant	Inactive
Pembina River	2.8										
M.C. Rutherford Potato Wash Co. Walhalla, N.D.		87.6	Food prod.	Inorganic	Not applicable	None	-	-	Not applicable	New plant	Inactive
Baldwin Potato Co. St. Thomas, N.D.		No defined drainage	Food Prod.	Inorganic	Not applicable	[g]	Sat.	Sat.	None	None	-
Fulson-Kennedy Potato Co. St. Thomas, N.D.		No defined drainage	Food Prod.	Inorganic	Not applicable	Primary[b]	Sat.	Sat.	None	None	-
Roseau River	h										
Wannaska Creamery Assn. Wannaska, Minn.		155	Food prod.	Organic	360	Minor[a]	Unsat.	Unsat.	360	New plant	Inactive
Ross Co-op Creamery Assn. Ross, Minn.		130	Food prod.	Organic	40	Minor[a]	Unsat.	Unsat.	40	New plant	Inactive
Creek		115									
North Star Creamery Assn. Badger, Minn.		7	Food prod.	Organic	190	Minor[a]	Unsat.	Unsat.	190	New plant	Inactive
Total					345,230				336,800		
Normal total excluding seasonal wastes -					125,230				74,800 (2,280)[i]		

---

[a] Septic tank.
[b] Discharge to slough--drainage to watercourse indefinite or nonexistent and primarily of local significance.
[c] Lagooned until spring runoff, then discharged at high water stage over shorter period than duration of campaign.
[e] To storm sewer, then to reservoir that drains to Sheyenne River
[f] Includes sanitary waste of West Fargo.
[g] Discharge to land.
[h] Discharges in Canada.
[i] Waste generally not reaching flowing water courses.

Table R-10. Red River Sub-Basin - Probable frequency of low mean monthly flows

Years of record[1]	Stream and location	Drainage area square miles	Low mean monthly discharge in c.f.s. that may be expected once in:				Low mean monthly flow of record
			2 yrs.	3 yrs.	5 yrs.	10 yrs.	
	SUMMER (JUNE-SEPT)						
48	Red River at Fargo, N.D.	6,800	132	62	19	0.0	0.0
67	Red River at Grand Forks, N.D.	30,100	880	558	390	150	20.3
16	Ottertail River below Pelican River near Fergus Falls, Minn.	1,810	30	19	14	13	7.99
15	Sheyenne River at Sheyenne, N.D.	1,980	0.0	0.0	0.0	0.0	0.0
12	Sheyenne River at Valley City, N.D.	8,360	9.2	1.4	0.1	0.0	0.0
25	Sheyenne River at West Fargo, N.D.	9,460	34	21	14	0.0	.01
26	Wild Rice River at Twin Valley, Minn.	888	30	17	8.6	9.0	7.46
42	Red Lake River at Crookston, Minn.	5,280	320	210	92	4.6	2.96
9	Two Rivers at Hallock, Minn.	625	4.0	1.0	0.9	19	8.87
	WINTER (DEC-FEB)						
33	Red River at Fargo, N.D.	6,800	48	26	14	0.5	0
64	Red River at Grand Forks, N.D.	30,100	454	300	200	100	2.87
14	Ottertail River below Pelican River near Fergus Falls, Minn.	1,810	41	27	22	17	10.8
14	Sheyenne River at Sheyenne, N.D.	1,980	0	0.0	0.0	0.0	0
11	Sheyenne River at Valley City, N.D.	8,360	5.0	3.9	0.1	0.0	0
20	Sheyenne River at West Fargo, N.D.	9,460	17	13	10	7.4	5.47
19	Wild Rice River at Twin Valley, Minn.	888	18	14	10	9.0	8.69
36	Red Lake River at Crookston, Minn.	5,280	180	130	56	26	15.6
4	Two Rivers at Hallock, Minn.	625	2.5	2	1	0.1	.1

---

[1] Based upon U.S.G.S. records

The slope of the lower half of the Sheyenne River changes from approximately 1.0 foot per mile from the mouth to river mile 70 to 1.5 feet per mile from river mile 70 to 245. Below Kindred and Horace to the mouth, the channel capacity, though insufficient for flood flows, appears adequate to carry reasonable diversion flows released upstream.

Laboratory Results

Numerous stream quality studies have been made in the past on the Red River of the North by the State Health Departments of North Dakota and Minnesota. These two States have acted cooperatively many times and the present study was no exception and reflects the neighborly spirit of these adjoining States.

Collection of stream samples was shared equally by the two States. The field men worked at the North Dakota Public Health Laboratory, Grand Forks, in setting up laboratory tests and assisting laboratory personnel wherever possible. Much can be done jointly even though individual State resources may be limited. Such an approach is essential on interstate streams.

Average and median values of laboratory data, sources of principal pollution, and location of many proposed and existing dams are presented in figures R-1 and R-2; individual laboratory results are included in appendix F. Sampling locations extended from above the Fargo-Moorhead region at river mile R-383 to near the International Boundary at river mile R-3. The mouths of major tributaries were also sampled.

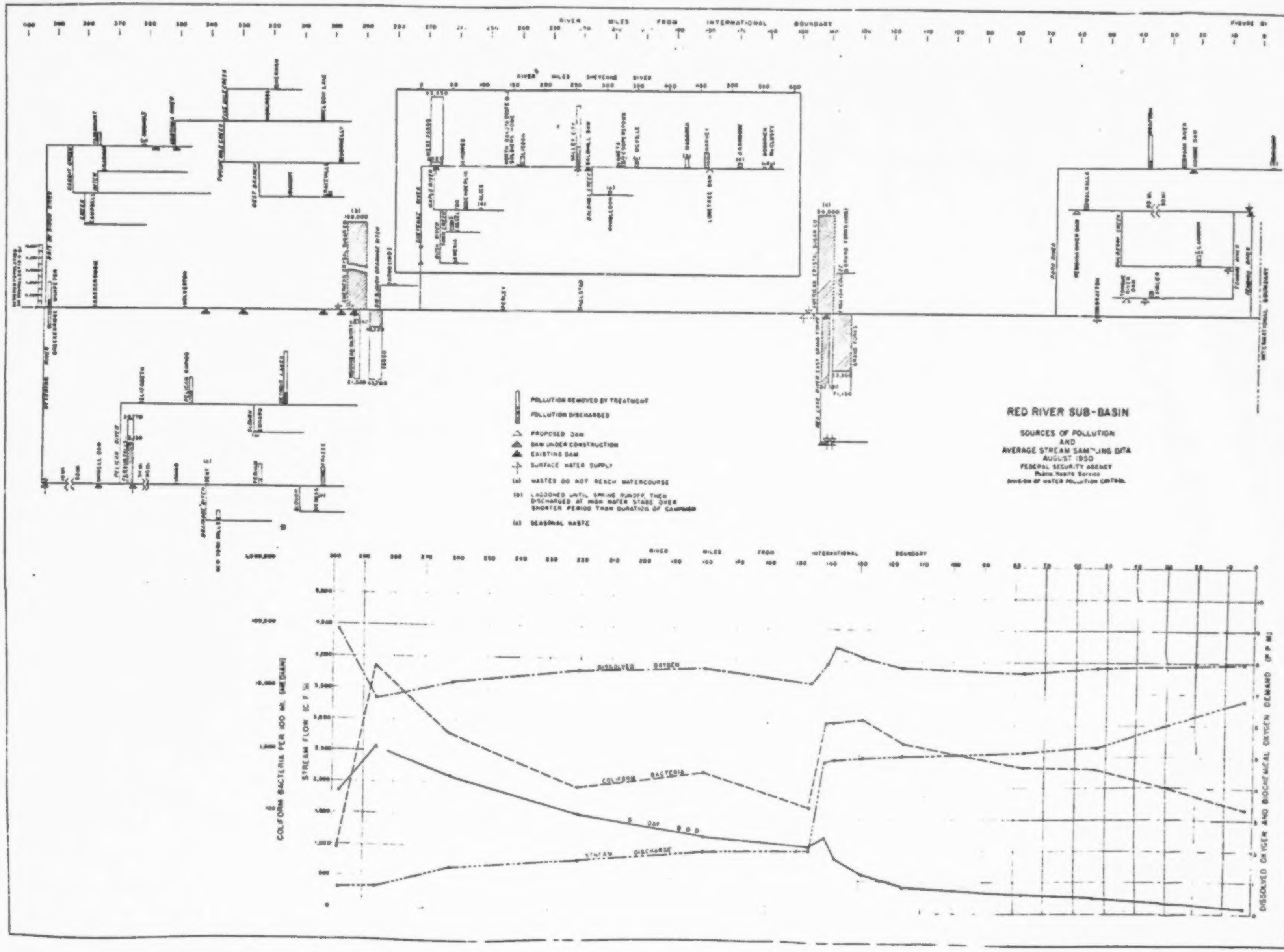
Thirteen stations on the Red River and 12 on tributaries were sampled during the summer of 1950, and 12 stations on the main stem and 8 on tributaries were tested during the following winter. A total of 595 samples were collected from these stations; 363 in summer and 232 in winter; 1,114 laboratory tests were made.

The results indicate two areas of significant pollution; one at the Fargo-Moorhead reach and the other below Grand Forks-East Grand Forks. However, stream discharges during the survey were high, minimizing pollutional effects.

Figure R-1 shows 1950 summer conditions. Flow at the Fargo water plant averaged 312 c.f.s.; average dissolved oxygen was high at 8.9 ppm. or 93 percent saturation; B.O.D. averaged a moderate 3.7 ppm., and median coliform value was low at 450 M.P.N. per 100 ml. The effect of pollution from the cities of Fargo and Moorhead dropped the dissolved oxygen to 6.7 ppm. or 70 percent saturation; increased radically the coliform density to 350,000 M.P.N. and increased the B.O.D. to 5.1 ppm.

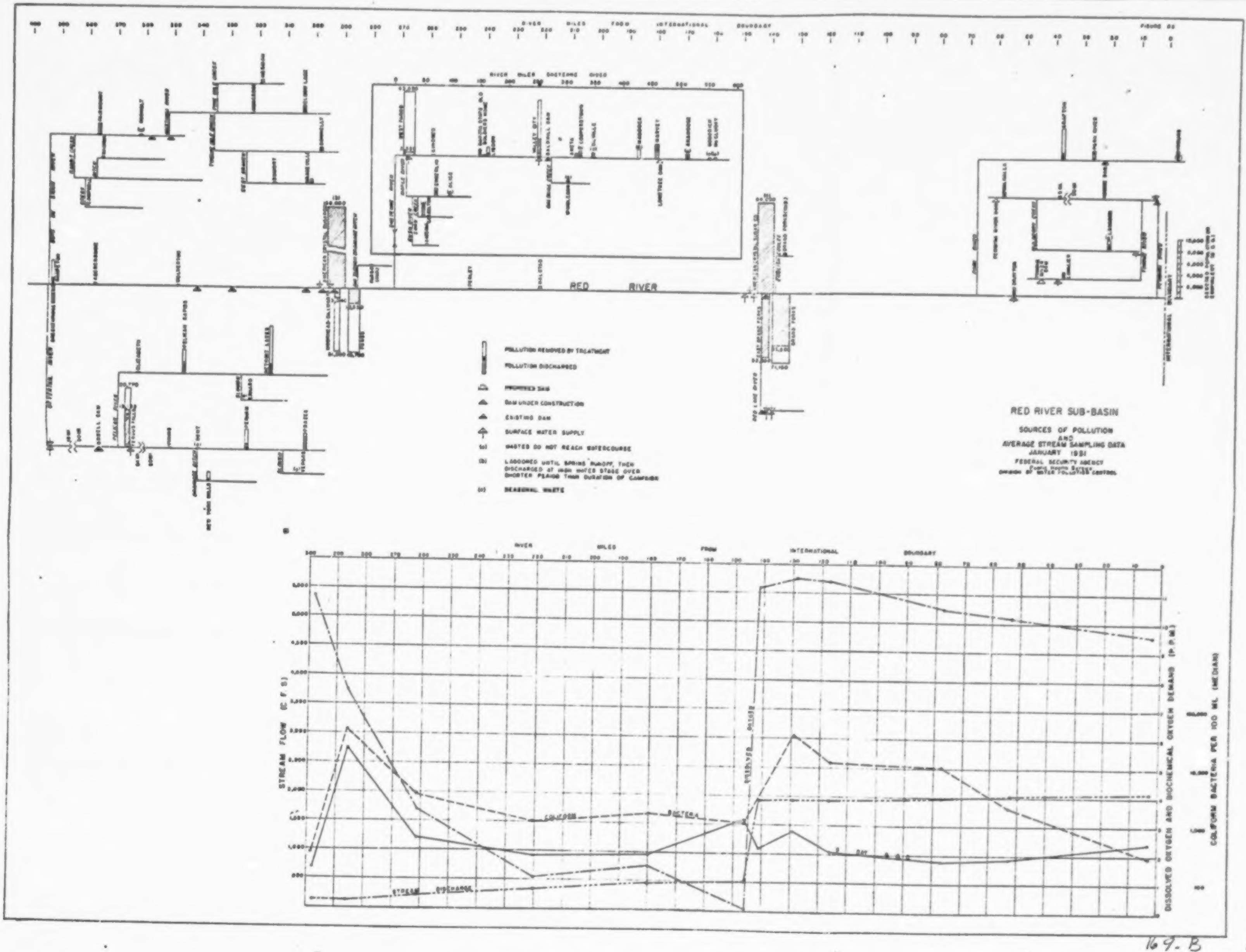
In progression downstream, natural biological recovery and stream dilution cause a gradual increase in dissolved oxygen, and a decrease in both B.O.D. and coliform density.

The pollution contributed by Grand Forks and East Grand Forks raises the B.O.D. slightly in the Red River and increases appreciably the coliform density from 2,000 to 49,000 M.P.N. per 100 ml. Other



RED RIVER SUB-BASIN

SOURCES OF POLLUTION
AND
AVERAGE STREAM SAMPLING DATA
AUGUST 1950
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL



RED RIVER SUB-BASIN

SOURCES OF POLLUTION
AND
AVERAGE STREAM SAMPLING DATA
JANUARY 1951
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

169-B

1

factors also influence the over-all stream condition in this vicinity. Red Lake River enters the Red River and increases stream flow. In fact, the Red Lake River quite generally discharges more water than the Red River. At the time of the survey a discharge of 975 c.f.s. in the Red River above Grand Forks was supplemented by 1,490 c.f.s. from the Red Lake River. Also, aeration over dams in both rivers near Grand Forks raised the dissolved oxygen in the Red River from 7.3 ppm. to 8.4 ppm.

Progressing downstream the dissolved oxygen decreased slightly and then remained about 8 ppm.; the B.O.D. decreased significantly to an extreme low of 0.2 ppm. at river mile 3; the median value for coliforms also decreased to an M.P.N. of 2,200 at river mile 3.

Of the tributaries sampled, the Sheyenne and Park Rivers had moderate coliform densities approaching 5,000 M.P.N. per 100 ml., indicative of municipal pollution. The Park and Snake Rivers had high B.O.D. coupled with high dissolved oxygen content, probably the result of photosynthesis. The Forest River showed only 62 percent dissolved oxygen saturation and a fairly high B.O.D. of 5.5 ppm.; the coliform density was low with an M.P.N. of 1,100.

Winter conditions during the period of sampling is shown in figure R-2. Samples were collected through a solid ice cover that extended from the Fargo reach to the impoundment at Grand Forks where open water occurred at Station 6. Below the Grand Forks area to Canada, solid ice cover again persisted.

Stream flow was high compared to normal low flow expectancies. River discharge, which averaged 130 c.f.s. at Fargo, increased to 500 c.f.s. above Grand Forks where it was supplemented by an additional 1,680 c.f.s. from the Red Lake River. Flow increased gradually downstream to average 2,080 c.f.s. at Station 1.

Above Moorhead-Fargo, the Red River averaged 10.7 ppm. dissolved oxygen, or 73 percent saturation. The average B.O.D. was low at 1.4 ppm., and the coliform density also low at M.P.N. of 450 per 100 ml. The discharge of pollution from Fargo and Moorhead depressed the dissolved oxygen to 7.5 ppm. and increased B.O.D. and coliform density to 5.6 ppm. and 54,000, respectively.

The effectiveness of the ice cover in preventing reaeration is illustrated by dissolved oxygen and B.O.D. results downstream from Fargo-Moorhead. The B.O.D. is partially stabilized by the oxygen in the stream, which is gradually reduced to about 1.1 ppm. at Station 9. The B.O.D. levels off at about 1.9 ppm. and the coliform density evens out at about 1,100.

At Station 7, above Grand Forks, the B.O.D. increased and the dissolved oxygen approached zero. The Red Lake River entered the Red River below Station 7 with an average of 12.2 ppm. dissolved oxygen. Flow in the former stream was over three times that of the Red. The added dilution with high dissolved oxygen water from the Red Lake River plus aeration over the dam at Grand Forks increase dissolved oxygen in the Red River to 11.4 ppm. The coliform density increased with contributed pollution. Progressing downstream to the International Boundary, the dissolved oxygen gradually decreased to 9.6 ppm.; coliform density decreased to 450 M.P.N. per 100 ml.; the B.O.D. varied in the neighborhood of 2 ppm. Most tributaries entered the Red River with significant oxygen deficiencies. However, as mentioned before, the Red Lake River showed a high dissolved oxygen value resulting from flow over a dam a short distance upstream from its confluence with the Red.

One of the critical factors in stream pollution over which little control can be effected is stream discharge. Prior to actual field sampling, discharge records are reviewed and a time selected for stream sampling when a period of low flow is expected so that laboratory results will give reasonable indication of contributed pollution. The past several years have been wet with high run-off and, in fact, oftentimes severe floods. Fairly high water occurred during this field sampling program as indicated in figures R-1 and R-2.

A similar study[1] was made several years ago--1938 to 1939--by the State Health Departments of Minnesota and North Dakota during periods of low stream flow. These data have been included in appendix F and plotted in figure R-3 to show winter and summer conditions. The months covered by the respective seasons are those specified in the State report.

Stream flow in the Red during the period of summer sampling in 1939 averaged 12 c.f.s. above Fargo and increased slowly to 27 c.f.s. above Grand Forks at Station 7. The Red Lake River supplemented Red River flow by 144 c.f.s. and flow then increased slowly below Grand Forks to reach 209 c.f.s. at Station 1. The pollution contributed by Moorhead and Fargo was indicated at Station 11 by a decrease in dissolved oxygen to 3.7 ppm. or 41 percent saturation and increases in B.O.D. to 10.6 ppm. and coliforms to 852,000 M.P.N. per 100 ml. The B.O.D. and coliform density dropped downstream from Fargo and oxygen recovery was rapid. The rapid recovery of the stream at the given low flows--maximum of 27 c.f.s. in the reach above Grand Forks--would indicate pooling of waters with riffles, affording reaeration and considerable photosynthesis by algae. Red Lake River increased flow in the Red River to 171 c.f.s. at Station 6. Pollution contributed by Grand Forks was noted by a drop in dissolved oxygen to 4.4 ppm. at Station 5 and a great increase in coliforms although B.O.D. showed only a slight increase. Stream recovery was rapid, and continued downstream as indicated by laboratory results at Stations 1, 2, and 3.

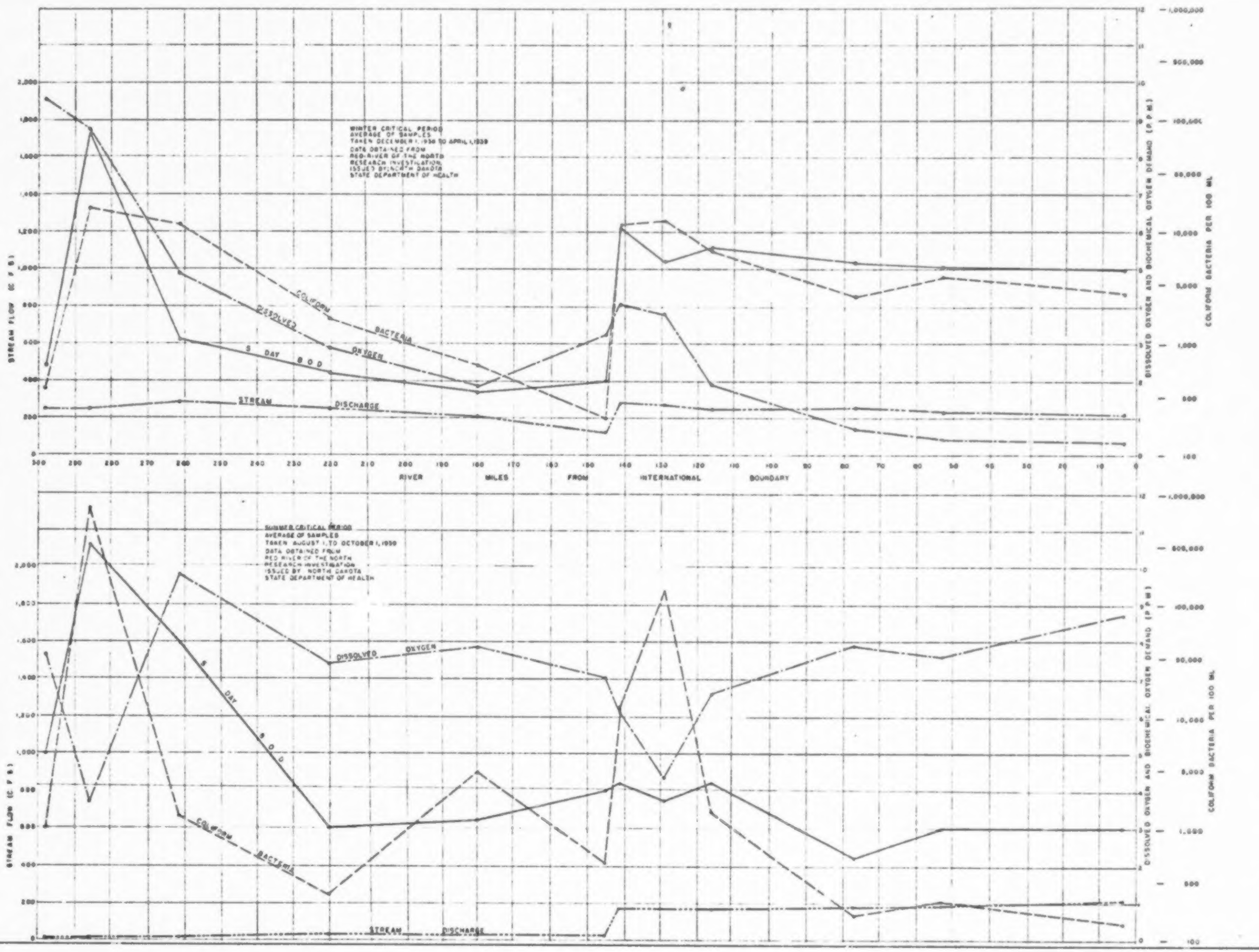
Winter conditions are also depicted in figure R-3. Stream flow was somewhat higher than during the summer period, averaging 242 c.f.s. at Station 12 above Fargo and 127 c.f.s. at Station 7 above Grand Forks. Flow from Red Lake River supplemented the Red River with 153 c.f.s. for a total 280 c.f.s. at Station 6; flow then gradually decreased to an average of 226 c.f.s. at Station 1.

The pollution contributed from the Fargo-Moorhead region effected a decrease in dissolved oxygen and a sharp increase in both B.O.D. and coliforms. Ice cover below Fargo prevented reaeration, resulting in a

---

[1] Red River of the North Research Investigation, issued by North Dakota State Department of Health, Division of Sanitary Engineering.

FIGURE 83



RED RIVER SUB-BASIN

AVERAGE STREAM SAMPLING DATA
DECEMBER 1, 1938 TO APRIL 1, 1939
AND AUGUST 1 TO OCTOBER 1, 1939

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

170 · A

gradual decrease in dissolved oxygen to 1.85 ppm. at Station 8. At the same station the B.O.D. was only 1.7 ppm. and the coliform density 790 M.P.N. per 100 ml. The introduction of pollution in the Grand Forks-East Grand Forks region increased B.O.D. to 6.1 ppm. and coliforms to 14,200. The dissolved oxygen increased slightly, probably caused by reaeration at the dam and then decreased downstream to a low of 0.4 ppm. at Station 1. The B.O.D. and coliforms decreased somewhat but continued at a high level in the stretch to the International Boundary.

Sampling during the spring breakup period in 1939 showed high coliforms below the Fargo and Grand Forks regions, and moderate B.O.D. values along the entire Red River reach under study. However, dissolved oxygen was above 9 ppm. except in the Grand Forks area where an average minimum of 7.27 was recorded. Stream flow which averaged 355 c.f.s. at Fargo increased to 1,090 c.f.s. above Grand Forks and 1,575 c.f.s. at Station 6. Maximum average discharge of 1,839 c.f.s. was recorded at Station 1.

Comparison of summer data collected in 1939 and with that collected in 1950 readily shows the effect of low stream discharges. Dissolved oxygen depressions were much more severe and B.O.D. values greater during low flow periods. In general, similar conditions may be noted when comparing winter data.

DISCUSSION

The development of the Red River of the North Sub-Basin has long been closely allied with problems of water utilization. Undoubtedly it is for this reason that many studies and reports have been written relating, either entirely or in part, to its water problems. It is known that well over 25 separate reports have been prepared on the subject. In addition, interstate compacts, commissions, and agreements have been evolved to handle the water need problem with associated pollution control and abatement phases. Yet much remains to be done. Although the interstate nature of the Sub-Basin complicates the approach to the over-all problem, past attempts have been well directed and appear to require only uniformity among the States in their pollution prevention and abatement enforcement. Revitalization of existing agencies or a new interstate body, with stronger enforcement agreements, would do much to achieve the goals of maximum beneficial water use that all have strived for.

During the past two decades the Red River Basin has experienced both drouth and flood conditions. The drouth of the thirties, the most severe on record, emphasized the importance of water and man's dependence on it, not only for his livelihood but for his very life.

Municipal Water Supplies

The undependability of existing water sources has been most keenly realized in the cities. It is known that an adequate potable water supply is one of the city's greatest assets, without which growth is impossible. During periods of very low flow, such as occurred in the Red River during the thirties, consumption of water had to be drastically reduced. Lack of water is often accompanied by pressure reductions in the distribution system, a condition that may permit the introduction of contamination and associated water-borne epidemics.

Sixteen municipalities in the Sub-Basin use surface water sources. Two utilize the Red River; three, the Ottertail; four, the Red Lake; two, tributaries of the Pembina; and one each on the Sheyenne, Goose, Tamarack, Pembina, and Two Rivers. All but two communities soften the water or provide taste and odor control or both.

Wahpeton and Breckenridge have had a history of inadequate water supplies but recent action has given relief. Those municipalities using water from the Sheyenne and Red Rivers have experienced water quantity and quality difficulties during low flow periods.

Many communities using ground sources for their water supplies also suffer from inadequate volume and poor water quality. Generally, the mineral content of ground water is quite high.

The regulation of streams in the Basin, coupled with importation of water by the Missouri-Souris project to achieve sustained minimum flows sufficient to satisfy the various needs, will be of enormous benefit to the communities. Besides providing an adequate volume, water quality will be improved. Municipalities drawing water from the Sheyenne and Red Rivers will be benefited directly as will communities, now using ground sources, that change to surface supplies. Increased stream flows may also raise ground water levels and improve ground water quality, thus benefiting communities a distance from the affected rivers. Table R-11 lists communities in the Sub-Basin as reported by the Bureau of Reclamation that may derive benefit by existing and proposed impoundments and diversions of the Missouri-Souris development program. Fruition of these benefits, however, will depend on flow routing and location of communities so that additional waters may be economically tapped.

Rural water supplies in this Sub-Basin depend on underground sources. These sources may not be readily obtainable in some instances and occasionally are undependable as to quantity and undesirable as to chemical and physical quality. During the drought, farmers could not obtain sufficient water for stock and had to reduce herds. Storage and distribution facilities to assist in maintaining sustained, adequate stream flows would be of considerable value to the farmers. Also, the recharge of ground water by irrigation practices may be beneficial. Generally then, experience indicates that unsupplemented surface waters during drought years may be inadequate and of poor quality. Underground water sources have seriously reduced yields or produce water of undesirable quality. The value of water to the economy of this region is greater than in most other areas.

Minimum desired flows for water pollution control as designated in table R-19 will control the quantity of flow recommended for water supplies. If a conservation program meets these flows, considerable benefits may accrue to domestic and industrial water users.

Table R-11. Red River Sub-Basin - Communities which may derive water supply benefits by existing and proposed impoundments and diversions[1]

Sheyenne River Valley

North Dakota

Cooperstown
Dazey
Esmond
Fort Ransom
Hannaford

Harvey
Heimdal
Kathryn
Kindred
Kloten

Lisbon
Luverne
McClusky
McVille
Maddock

Oberon
Pekin
Selz
Sheyenne
Tolna

Valley City
Warwick

Wild Rice River Valley

North Dakota

Cogswell

Red River Valley

North Dakota

Bowesmont
Drayton
Fargo
Grand Forks
Horace

---

[1] From Bureau of Reclamation.

It is not the intent of this report to evaluate in detail the dollar benefits that may result to communities of the Sub-Basin from improved water supplies. In the General Section a method of achieving an annual cost benefit has been discussed. The Municipal Water Supply Unit, Bureau of Reclamation, and its counterpart in the Corps of Engineers, have been studying these phases and will appraise the benefits.

The Corps of Engineers in cooperation with the State Health Departments of Minnesota and North Dakota, in the report "Water Use Survey--International Souris-Red Rivers Engineering Committee--Red River Watershed," presented a unique analysis of benefits resulting from improvement in quantity and quality of municipal supplies. A rating scheme comparing characteristics of the existing supply with those to be expected after project development was established. Quantity rated 25 points, healthfulness and bacteriological content 20 points, hardness 15 points, nearness and availability 15 points, taste 10 points, corrosiveness and incrustativeness 10 points, and suitability for lawn and garden watering 5 points, for a total of 100 points. Values of ratings were assigned after conferring with State Health Departments of Minnesota and North Dakota. The report describes the method and individual benefits. It was concluded that water supply benefits to be realized under the coordinated water plan for cities of the Red River Basin may be estimated at $222,930 annually.

Industrial Water Supplies

Industry, in addition to using municipal supplies, has developed private or supplemental sources. Two beet sugar refineries use about 11 M.G.D. of surface waters during the beet sugar operating season. Two electric generating plants use about 40 M.G.D. for cooling water; a packing plant uses 1 M.G.D.; three potato washers use 0.2 M.G.D., and a flour mill uses 0.1 M.G.D. Ground water is used by 100 various industries to the extent of about 2 M.G.D.

During the drought of the '30s many industries were forced to operate with a limited supply of water, which in some cases resulted in periodic cessation of operation. Industry, which requires an adequate supply of good water, has not been able to develop in the area because of the possibility of a recurrence of water shortage.

With the completion of the development program and the assurance of an adequate water supply of good quality there would be room for considerable industrial expansion. Many industries have expressed a desire to locate in the Red River Valley because of the close proximity of raw materials; however, water supply and waste disposal problems have prevented this development. Benefits to be derived by industry would undoubtedly be widespread if a good water supply were provided.

Sources of Pollution and Status of Sewage Treatment

Of the 94 communities listed in table R-8 as sources of municipal pollution, 51 are in Minnesota, 41 in North Dakota, and 2 in South Dakota. These communities are grouped in table R-12 according to their existing treatment facilities.

Twenty-two communities providing no treatment are:

Minnesota

Argyle
Breckenridge
Climax
Crookston
Donnelly
East Grand Forks
Fertile
Halstad
Hawley
Herman
Kennedy
Mahnomen
Sunnyrest Sanatorium
Twin Valley

North Dakota

Abercrombie
Amenia
Anamoose
Drayton
Fairmount

Harvey
Hillsboro
Walhalla

Nine towns have septic tanks (minor treatment):

North Dakota

Casselton
Cavalier
Cooperstown
Enderlin
Forman
Hankinson
Lidgerwood
McVille
Wimbledon

Sewage is given primary treatment at:

Minnesota

Ada
Blackduck
Callaway
Elbow Lake
Fergus Falls

Frazee
Graceville
Hallock
Kelliher
Lancaster

Northome
Ottertail Sanatorium
Red Lake Falls
Stephen
Warren

Wolverton

North Dakota

Finley
Goodrich
Grand Forks
Hatton
Langdon
Larimore
Mayville
McClusky
Milnor
Northwood
Park River

South Dakota

Rosholt
Veblen

Secondary sewage treatment is provided at:

Minnesota

Bagley
Barnsville
Battle Lake
Clearbrook
Detroit Lakes

Dilworth
Fosston
Lake Julia Sanatorium
Lake Park
McIntosh

Moorhead
New York Mills
Oakland Park Sanatorium
Pelican Rapids
Perham

Red Lake Indian Agency
Roseau
Rothsay
Sand Beach Sanatorium
Thief River Falls

Ulen

North Dakota

Fargo
Grafton
Kindred
Lisbon
Old Soldiers' Home

Southwest Fargo
Valley City
Wahpeton
West Fargo

Lagoons provided effective treatment for municipal sewage of four North Dakota communities--Maddock, Hope, Portland, and Michigan City.

Table R-12. Red River Sub-Basin - Existing municipal* sewage treatment facilities

Degree of treatment provided	Number		Population served
	Municipalities	Plants	
Minor[a]	9	10	7,650
Primary	29	30	60,460
Secondary	34[b]	32	95,480
No treatment	22	-	27,450

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

[a] Septic tank.

[b] Includes 4 new systems under construction.

Table R-13, "Adequacy of existing waste treatment facilities," indicates that a program of increasing capacity and improving operation of municipal sewage plants is needed. Of the 68 municipal sewage treatment plants only 36 have satisfactory capacity, and 42 have satisfactory operation.

Table R-13. Red River Sub-Basin - Adequacy of existing waste treatment facilities

Existing treatment facilities	Number	Adequacy with relation to: Capacity		Adequacy with relation to: Operation	
		Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
Municipal*	68	36	32	42	26
Industrial**	57	22	35	22	35

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Of the 85 sources of industrial pollution (table R-9), 50 are in Minnesota and 35 in North Dakota. All of the industries either manufacture or process foodstuffs. Organic waste originates from 76 industries and 9, all potato washing plants, produce primarily inorganic waste, mostly silt. Fifty-seven have waste treatment facilities, of which 22 have satisfactory capacity and 22 have satisfactory operation (table R-13).

Figures R-1 and R-2 depict graphically sources of pollution in the Sheyenne and Red River Valleys. It is primarily in the Sheyenne and Red River Valleys from Fargo-Moorhead to the International Boundary where additional flow by water importation from the Missouri River may benefit communities. The largest sources of pollution are contributed from two general reaches--Fargo-Moorhead and Grand Forks-East Grand Forks.

In the Fargo-Moorhead region, Fargo, Moorhead, and Dilworth provide effective secondary treatment. A beet sugar plant produces a seasonal waste high in B.O.D. but it is lagooned for discharge during high spring runoff which satisfactorily handles the situation. A meat packing plant at West Fargo, 26 miles up the Sheyenne River, gives its waste an exceptionally high degree of treatment with a tertiary process.

Only minor sources of pollution are located downstream from Fargo until the Grand Forks-East Grand Forks region is reached. Here East Grand Forks discharges raw sewage and Grand Forks provides only primary treatment. Industrial wastes are also discharged untreated in this reach, particularly that from a sugar beet refinery and a potato products plant. These latter wastes and municipal sewage from East Grand Forks reach the Red River above the dam at Grand Forks. Wastes emanating from Grand Forks, both municipal and industrial, are discharged below the dam.

Stream Conditions

The detailed account of stream conditions in the Red River is given in appendix E under the title "Limnological Characteristics." The Red River and lower stretches of its major tributaries are all similar in appearance, having mud and muck bottoms, muddy banks, frequent driftwood accumulations in channels, and tree covered borders.

The water chemistry of the Red River is largely the result of dilution of moderately mineralized waters from North Dakota tributaries with softer waters coming from swamp and marsh areas along the upper reaches of major Minnesota tributaries. During open water periods, except during extreme low flows, oxygen is supplied almost entirely by aeration as turbidity is great enough to restrict plant growth. Dams above Fargo-Moorhead and below Greater Grand Forks aid considerably in aeration and are largely responsible for oxygen present under ice cover. Oxygen levels decline below each of these larger municipal areas, although the sag below Greater Grand Forks is delayed by aeration afforded by the dam at Riverside Park.

B.O.D. from natural sources appears to vary over the seasons from 2.5 to 3.0 ppm. These levels are raised considerably by waste discharges. Interference to B.O.D. tests may be occasioned by zinc and copper salts in the stretch below the mouth of the Red Lake River.

Bottom organism samples taken during September 1950 and February 1951 indicate that pollution in the Red River, although moderate over long stretches, is heavily concentrated in certain localities. Accumulations of waste solids occur in various localities and frequently at considerable distances from their sources. Flows occurring during ice breakup seemingly exert the greatest influence upon distribution of waste solids. These benthic studies aptly illustrate possibilities for wastes contamination in regions remote from their sources.

Plankton organisms, by their response to inorganic salts produced by oxidation of waste products, indicated that stream recovery from Fargo-Moorhead pollution is usually attained in the reach below the mouth of the Sheyenne River; and that recovery from Greater Grand Forks wastes usually does not occur until water has reached the most northerly stretches of the Red River in the United States.

Sewage and Waste Treatment Needs

The quality of water in the stream may be protected by installation of municipal sewage and industrial waste treatment plants designed to lessen pollutional loads discharged to streams. Generally, severe pollution will be abated by local and State interests in order to protect public health and to prevent nuisance conditions. Treatment requirements depend upon the nature, volume, and point of discharge of contributed wastes; volume of flow in the stream; and downstream water uses.

The degree of sewage treatment required is generally based upon normal low flow expectancies. The States of Minnesota, North Dakota, and South Dakota regard primary treatment for the removal of settleable solids and floating matter to prevent sludge beds and unsightly nuisances as a minimum requirement. When normal minimum flows are below the limit required for the dilution of primary treatment effluents, secondary and possibly tertiary treatment is necessary. Secondary treatment involves oxidation by biological means, and tertiary treatment is a combination of biological oxidation processes or a combination of chemical treatment and a biological oxidation process. Norman minimum flow may be defined as the stream discharge occurring at such a frequency as to form a firm basis for sewage treatment design. It has been taken in this report as the minimum mean monthly flow to be expected to occur once in ten years because of stream conditions and water use encountered. Downstream uses such as public water supply, private water supplies, irrigation, recreation, and ice harvesting, may necessitate chlorination to disinfect sewage treatment plant effluents.

Sewage and waste treatment needs are listed in table R-14. These needs are founded upon conditions observed during this pollution study coupled with analyses of available discharge records, and do not reflect possible increase in minimum flow resulting from stream regulation or importation of Missouri River water.

The scarcity of water during low stream flow and the importance of water uses in the Red River Sub-Basin have caused the various State water pollution control agencies to crystallize their thoughts regarding sewage treatment. As indicated in table R-14, all organic wastes not now effectively treated are shown as needing secondary treatment. In a few instances wastes, essentially inorganic in nature, are shown as requiring only primary treatment for removal of settleable material. The table does not indicate, however, those places where an exceptionally high degree of secondary treatment or possibly tertiary treatment may be required. Many of these locations occur where stream discharges approach or reach zero for protracted periods during critical times.

Pertinent to the States' requirements on sewage treatment in the Red River Valley are the cooperative approaches made by the State agencies in an effort to achieve a uniform pollution abatement and prevention program. In 1938 the States of South Dakota, North Dakota, and Minnesota, by formal agreement, executed with the specific authorization of their respective legislatures and approval of the Congress, entered into an interstate compact creating the Tri-State Waters Commission (see General Section). One of the duties with which the Commission is charged is the study of the various water problems relating to water supply in the Tri-State Waters area. The 75th Congress, which gave consent to this compact, specifically states that it is an "Act . . . . . relating to the utilization of, the control of the floods of, and the prevention of the pollution of the waters of the Red River of the North and streams tributary thereto." In recent years the Commission operating under this Act has not been active.

To further pollution control in the Basin, the Departments of Health of the States of North Dakota, South Dakota, and Minnesota, the North Dakota Water Conservation Commission, the Minnesota Department of Conservation, and the South Dakota agency concerned with water conservation, formed an informal Red River Drainage Basin Interstate Sanitation

Table R-14. Red River Sub-Basin - Project list

Name	Population equivalent	Treatment: Existing	Treatment: Needs (or equivalent industrial waste control measures)	Project
Minnesota				
Elbow Lake	1,380	Primary	Secondary	Addition
Norcross				
Norcross Co-op. Cream. Assn.	40	Minor[a]	Secondary	New plant
Herman	780	None	Secondary	New plant
Donnelly	780	None	Secondary	New plant
Graceville	790	Primary	Secondary	Addition
Dumont				
H. J. Zobach	280	Minor[a]	Secondary	New plant
Nashua				
Nashua Co-op. Cream Assn.	290	Minor[a]	Secondary	New plant
Campbell				
The Village Market	180	Minor[a]	Secondary	New plant
Frazee	2,520	Primary	Secondary	Addition
Frazee Cream. Co.	610	None	Secondary	New plant
Vergas				
Vergas Cream. Co.	170	Minor[a]	Secondary	New plant
Dent				
Dent Co-op. Cream. Assn.	140	Minor[a]	Secondary	New plant
Vining				
Vining Co-op. Cream. Assn.	170	None	Secondary	New plant
Fergus Falls	20,730	Primary	Secondary	Addition
Erhard				
Farmer Co-op. Cream. Assn.	60	Minor[a]	Secondary	New plant
Pelican Rapids				
Farmers Co-op. Cream. Assn.	1,030	None	Secondary	New plant
Elizabeth				
Elizabeth Cream.Assn.	80	None	Secondary	New plant
Breckenridge	3,100	None	Secondary	New plant
Wolverton	360	Primary	Secondary	Addition
Calloway	280	Primary	Secondary	Addition
Hawley	2,980	None	Secondary	New plant
Lake Audubon				
Big "S" Co-op. Cream. Assn.	190	Minor[a]	Secondary	New plant
Audubon Co-op. Cream. Assn.	100	Minor[a]	Secondary	New plant
Perley				
Perley Co-op. Cream Assn.	50	None	Secondary	New plant
Ogema				
Ogema Creamery	670	None	Secondary	New plant
Waubun				
Waubun Creamery	130	None	Secondary	New plant
Mahnomen	1,620	None	Secondary	New plant
Flom				
Flom Co-op. Cream. Assn.	100	Minor[a]	Secondary	New plant
Twin Valley	830	None	Secondary	New plant
Halstad	720	None	Secondary	New plant
Ada	2,880	Primary	Secondary	Replacement[b]
Shelly				
Shelly Farmers Co-op. Creamery	150	Minor[a]	Secondary	New plant
Winger				
Winger Farmers Cream. Co.	110	Minor[a]	Secondary	New plant
Rindal				
Rindal Co-op. Cream. Assn.	220	None	Secondary	New plant
Sundahl				
Sundahl Co-op.Cream.Assn.	50	None	Secondary	New plant
Fertile	2,900	None	Secondary	New plant
Beltrami				
Beltrami Co-op. Cream. Assn.	50	None	Secondary	New plant
Climax	100	None	Secondary	New plant
Northome	200	Primary	Secondary	Replacement
Kelliher	240	Primary	Secondary	Addition
Blackduck	1,080	Primary	Secondary	Replacement
Gatzke				
Hollis Co-op.Cream.Assn.	60	Minor[a]	Secondary	New plant
Grygla				
Grygla Co-op.Cream.Assn.	90	None	Secondary	New plant
Holt				
Holt Co-op.Cream.Assn.	100	None	Secondary	New plant
Goodridge				
Farmers Co-op.Cream. Assn.	90	Minor[a]	Secondary	New plant
St. Hilaire				
St. Hilaire Co-op. Creamery	170	None	Secondary	New plant
Leonard				
Leonard Co-op.Cream.Co.	90	Minor[a]	Secondary	New plant
Plummer				
Plummer Co-op. Cream. Assn.	60	None	Secondary	New plant
Minnesota (Cont'd)				
Gonvick				
Gonvick Co-op.Cream.Assn.	100	Minor[a]	Secondary	New plant
Gully				
Gully Farmers Co-op Cream.	60	None	Secondary	New plant
Oklee				
Oklee Co-op. Assn.	110	None	Secondary	New plant
Erskine				
Erskine Cream. Assn.	120	Minor[a]	Secondary	New plant
Mentor				
Mentor Cream. Assn.	60	Minor[a]	Secondary	New plant
Fisher				
Fisher Co-op.Cream.Assn.	180	None	Secondary	New plant
Red Lake Falls	1,790	Primary	Secondary	Enlargement
Red Lake Falls Rend.Co.	150	Primary	Secondary	Enlargement
Crookston	7,500	None	Secondary	New plant
Sunnyrest Sanatorium	80	None	Secondary	New plant
East Grand Forks	6,280	None	Secondary	New plant
Potato Products Corp.	26,300	None	Secondary	New plant
American Crystal Sug. Co.	94,000	Minor	Secondary	New plant
Viking				
Farmers Co-op.Cream.Assn.	80	Minor[a]	Secondary	New plant
Warren	1,590	Primary	Secondary	Replacement
Middle River				
Middle River City Co-op. Creamery	110	None	Secondary	New plant
Newfolden				
Farmers Coop.Cream.Assn.	100	None	Secondary	New plant
Argyle	1,050	None	Secondary	New plant
Standquist				
Standquist Cream. Co.	100	Minor[a]	Secondary	New plant
Stephen	1,080	Primary	Secondary	Addition
Kennedy	290	None	Secondary	New plant
Greenbush				
Farmers Co-op.Cream.Assn.	120	Minor[a]	Secondary	New plant
Karlstad				
Karlstad Co-op. Creamery	40	Minor[a]	Secondary	New plant
Halma				
Farmers Co-op. Creamery	60	None	Secondary	New plant
Lake Bronson				
Community Creamery	100	Minor[a]	Secondary	New plant
Hallock	1,790	Primary	Secondary	Addition
Lancaster	390	Primary	Secondary	New plant
Wannaska				
Wannaska Creamery Assn.	360	Minor[a]	Secondary	New plant
Ross				
Ross Co-op.Creamery Assn.	40	Minor[a]	Secondary	New plant
Badger				
North Star Creamery Assn.	190	Minor[a]	Secondary	New plant
North Dakota				
Fairmount	2,080	None	Secondary	New plant
Forman	400	Minor[a]	Secondary	New plant
Lidgerwood	1,100	Minor[a]	Secondary	New plant
Wyndmere				
Wyndmere Creamery Co.	110	None	Secondary	New plant
Hankinson	1,660	Minor[a]	Secondary	New plant
Fargo	43,700	Secondary	Add'l. treat.	Enlargement
Red Owl Warehouse	190	Secondary	Add'l. treat.	Addition
Anamoose	900	None	Secondary	New plant
Harvey	2,500	None	Secondary	New plant
McVille	800	Minor[a]	Secondary	New plant
Cooperstown	1,060	Minor[a]	Secondary	New plant
Aneta				
Aneta Creamery & Produce	650	Minor[a]	Secondary	New plant
Farmers Union Locker Plant	120	Minor[a]	Secondary	New plant
Wimbledon	600	Minor[a]	Secondary	New plant
Alice				
Stanglers Meat Market	220	None	Secondary	New plant
Enderlin	1,400	Minor[a]	Secondary	New plant
Casselton	1,800	Minor[a]	Secondary	New plant
Hunter				
Hunter Creamery	260	None	Secondary	New plant
Northwood	810	Primary	Secondary	Addition
Finley	940	Primary	Secondary	Addition
Portland	800	Lagoon	Secondary	New plant[b]
Mayville	2,000	Primary	Secondary	New plant
Hatton				
Dean Oaking Potato Wash.	Not applicable	None	Primary	New plant
Hillsboro	2,640	None	Secondary	New plant
Grand Forks	39,850	Primary	Secondary	Addition
N.D.Mill & Elevator	2,500	None	Secondary	New plant
Rogers Bros. Seed Co., Food Products Div.	6,700	Primary	Secondary	Addition
Armour & Co.	32,100	Minor[a]	Secondary	New plant
Meat Service Co.	600	Minor[a]	Secondary	New plant
Larimore	3,320	Primary	Secondary	New plant
Manvel				
Spencer Creamery Co.	230	None	Secondary	New plant
Fordville				
Fordville Creamery	230	Cesspool	Secondary	New plant
Park River	1,600	Primary	Secondary	Replacement
Drayton	950	None	Secondary	New plant
Drayton Creamery	640	Minor[a]	Secondary	New plant
Walhalla	1,000	None	Secondary	New plant
W.C.Rutherford Potato Wash.	Not applicable	None	Primary	New plant
Cavalier	1,200	Minor[a]	Secondary	Replacement
South Dakota				
Veblen	540	Primary	Secondary	Addition

---

[a] Septic tank
[b] Under construction

Committee in 1944 to ". . . . . proceed with such studies and investigations as shall be necessary to determine the nature, degree, causes, and sources of pollution, and shall recommend plans and methods for interstate cooperation on the part of said States in dealing with pollution problems in the drainage basin of said river and for action by the proper authorities in specific cases involving such pollution." This committee, which has been and still is active, has done much to point up pollution problems in the Red River Valley. They have cooperated effectively with Federal agencies in the water conservation and development program. In 1949 the committee set up standards recommended for use by the respective regulatory agencies for sewage and waste treatment facilities discharging into the Red River of the North and the tributaries as they affect the Red River, as follows:

"It is recommended that industry and municipalities treat their wastes to the point where the average daily composite 20° C., 5-day B.O.D. is 25 ppm., suspended solids 30 ppm., with no peaks running over 50 ppm. 20° C., 5-day B.O.D. and 60 ppm. suspended solids. Chlorination shall not be used as means of obtaining the B.O.D. reductions, although it may be required for other purposes. Certain types of industrial wastes, such as those resulting from the processing of agricultural products, may have to be considered on an entirely different basis.

"It is further recommended that these standards be considered as general only, and that they be subject to modification to meet specific pollutional problems as they develop."

Subsequently, these standards were adopted by the respective State regulatory agencies. The criteria essentially establish the principle of secondary treatment for all organic wastes discharging to the Red River or to tributaries where they have an appreciable effect on the Red River.

Waste treatment requirements (table R-15) show that 32 municipalities need new plants, 15 should enlarge or add to their existing plants, 6 should replace their plants, and 37 need no project. Table R-16 indicates that no formal action has been taken by 39 municipalities, 5 are preparing plans, 7 have final plans approved, and 6 plants are under construction. Progress in municipal pollution abatement (table R-17) has taken an upward trend since the close of World War II. One plant was constructed in each of the years 1946 and 1948, none in 1947, 3 in 1949, and 4 in each of the years 1950 and 1951.

Of 85 industries in the area, 61 need new waste treatment plants, 3 should enlarge existing facilities, and 21 require no further treatment. Sixty-one industries have taken no action, 2 have plans under preparation, and 1 has a plant under construction. One industrial waste treatment plant has been constructed in the period 1946-1951.

Table R-15. Red River Sub-Basin - Municipal and industrial waste treatment needs

Needs	Municipal* Number	Municipal* Population served by facilities	Industrial** Number
New plant	32	36,670	61
Enlargement or additions to existing plant	15	83,520	3
Replace existing plant	6	6,310	0
No project required	37	62,700	21

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

Table R-16. Red River Sub-Basin - Status of municipal* and industrial** action on pollution abatement needs

Status of project	Number Municipal	Number Industrial
No formal action	39	61
Abatement ordered	0	0
Plans under preparation	5	2
Final plans approved	7	0
Construction awaits financing	0	0
Under construction	6[a]	1

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

[a] Includes 4 new systems.

Table R-17. Red River Sub-Basin - Progress in pollution abatement

	Municipal*		Industrial**	
Year	Plants completed	Design population	Plants completed	Amount of waste treated
1946	1	800	0	-
1947	0	-	1	126,000 P.E.
1948	1	1,000	0	-
1949	3	1,825	0	-
1950	4	11,000	0	-
1951	4	3,550	0	-

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

A beet sugar refinery at East Grand Forks presents a special waste treatment problem. This plant operates seasonally during late fall and early winter and discharges organic wastes equivalent to that from 94,000 persons. The waste, untreated, reaches the stream during critical ice cover. A plant producing similar wastes at Moorhead provides lagoons and discharges the lagooned wastes into the river during high spring runoff, which meets with the approval of the State water pollution control agencies. Such a method should be considered at the East Grand Forks refinery. A potato products plant, also at East Grand Forks, discharges an organic waste with a population equivalent of over 26,000. A high degree of treatment will be necessary here to achieve the Red River Drainage Basin Interstate Sanitation Committee standard (25 ppm. B.O.D.) for treatment plant effluents.

Flow Needs Evaluation

The development program may alter appreciably existing low flow patterns in many of the streams of the Sub-Basin. Increased minimum flows may permit benefits in a form of lower degree of sewage treatment, improved quality and increased volume of water for municipal and industrial users, and enhanced fish and wildlife propagation.

Specified flows are those required to assimilate residual oxygen consuming matter remaining after a designated degree of waste treatment has been provided without lowering the oxygen content of the stream below that required for balanced aquatic life. Because of existing stream conditions and low flows that approach zero in numerous instances, the basis for treatment benefits has been taken as an exceptionally high degree of secondary treatment, or a tertiary degree of treatment, giving 85 percent B.O.D. removal. Thus additional flows, which will permit normal secondary treatment of 75 percent B.O.D. removal or primary treatment of 35 percent removal, will give tangible benefits in the form of lower costs for a lesser degree of sewage treatment. Of particular importance to evaluation of stream flows has been the winter ice condition which prevents reaeration.

It has been assumed that sugar beet refinery wastes are being adequately provided for under existing conditions. This has been based upon the fact that the sugar beet plant at Moorhead, Minnesota, lagoons its waste during periods of ice cover and discharges it during spring high water. This method of treatment has met with approval, subject to modification or revocation as provided by law, of the State Health Departments of Minnesota and North Dakota. A similar method of disposal by the other beet sugar plant in East Grand Forks would no doubt take care of the waste produced.

Table R-18 shows benefits that may accrue to the development program if specified minimum flows are met. These flows provide a basis for comparing additional treatment costs against the value of water for other uses. The sites selected are those which would be affected by the importation of water from the Missouri River and includes communities on the Sheyenne River and the principal communities on the Red River. Table R-19 shows monthly flow variations needed at three specific locations: West Fargo on the Sheyenne River, Fargo-Moorhead reach on the Red River, and Greater Grand Forks also on the Red River.

Winter conditions in the Red River below Fargo-Moorhead show an interesting picture of oxygen depletion. In fact the amount of oxygen utilized, shown by laboratory analyses, would tend to indicate that a much larger source of pollution existed. Upon further study it was realized that flow accretion was ground water which probably contained very little or no dissolved oxygen. Such dilution waters would decrease dissolved oxygen concentrations. Applying the stream flow figures obtained during this survey, as indicated on figure R-2, it would appear that this fact is borne out. Accordingly it was calculated that an additional 200 c.f.s. passing over the dam above Fargo would be necessary to provide sufficient oxygen for the accreted waters. The winter estimated flows for the Fargo-Moorhead area include this value.

A further study was made to compare benefits from supplemental flows against cost of these waters. The Bureau of Reclamation District Office at Bismarck, North Dakota, estimated that pumpage costs would approximate $1.00 for each acre-foot of Missouri water pumped over the divide into the Sheyenne River. Stream flow records covering a period from 20 to 40 years were then analyzed to obtain an average figure for the additional water needed to supplement Red River flows to achieve present desirable flows as specified in table R-19. For example, during the month of January, 32 years of record would indicate that for 2 years out of 32 years there would be sufficient flow in the Red River for sanitary purposes. For the remaining 30 years the average flow was 88.5 cubic feet per second. The flow regulation program then would have to provide an average of 16,780 acre-feet during the month to permit normal secondary treatment. Similarly, to permit primary treatment of sewage, January flows for the 32 years of record, which averaged 109.5 c.f.s., would have to be supplemented every year by an average of 30,500 acre-feet. During the month of April, 40 years of record show that at no time would supplemental flows be needed to permit a basic treatment of 75 percent B.O.D. removal. For primary treatment only one year out of the 40 would it be necessary to provide supplemental flows. This value would average 42 acre-feet per year. Following this procedure for all months, and

Table R-18. Red River Sub-Basin - Flow needs[1] at given locations and cost evaluation

Municipality	Stream	River mile location	Minimum normal flow[1] c.f.s.	Primary (35%) treatment minimum flows[1] c.f.s.	Secondary (75%) treatment minimum flows[1] c.f.s.	Annual tangible monetary benefits possible if flow in Column 5 provided	Annual tangible monetary benefits possible if flow in Column 6 provided
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Harvey, N.D.	Sheyenne	462	0	11	5	$ 10,600	$ 3,900
Valley City, N.D.	"	253	.	40	15	27,600	9,200
West Fargo, N.D.	"	26	9	200	70	132,000	44,000
Breckenridge, Minn.	Red	392)				14,400	4,800
Wahpeton, N.D.	"	392)				19,800	6,600
Moorhead, Minn.	"	292.2)	0	270	100	69,800	23,300
Fargo, N.D.	"	286.2)				139,800	46,600
East Grand Forks	"	142)	155	370	140	101,000	33,700
Grand Forks	"	140)				225,300	75,200
TOTAL						$740,300	$247,300

---

[1] Summer flows.

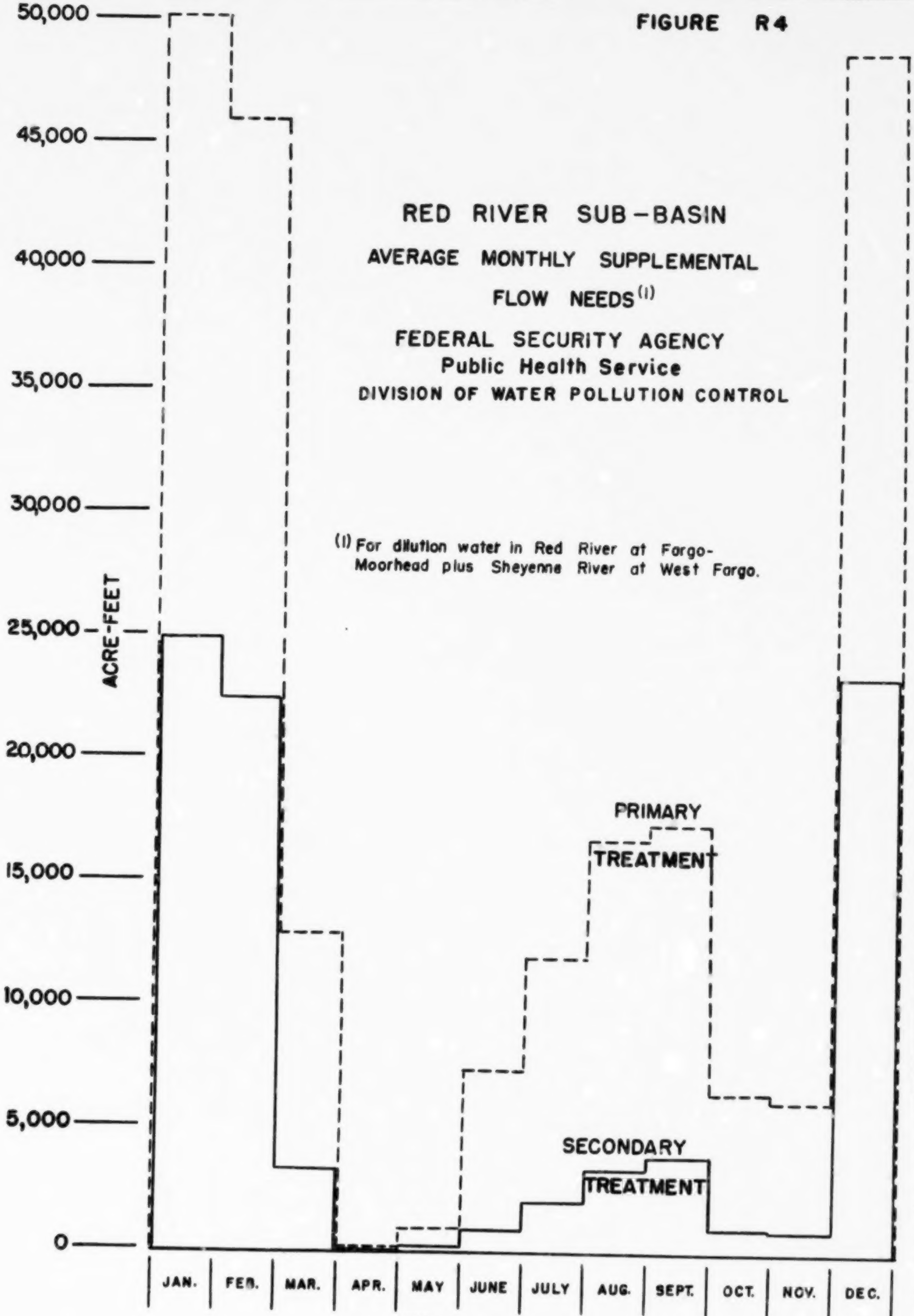


FIGURE R4

RED RIVER SUB-BASIN
AVERAGE MONTHLY SUPPLEMENTAL FLOW NEEDS[1]
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

[1] For dilution water in Red River at Fargo-Moorhead plus Sheyenne River at West Fargo.

Table R-19. Red River Sub-Basin - Flow needs in c.f.s. by months for critical locations

	West Fargo				Fargo-Moorhead				Greater Grand Forks			
	Present		Future(1980)		Present		Future(1980)		Present		Future(1980)	
Month	Primary 35%	Secondary 75%	Primary 45%	Secondary 85%	Primary 35%	Secondary 75%	Primary 45%	Secondary 85%	Primary 35%	Secondary 75%	Primary 45%	Secondary 85%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
January	350	150	600	180	600	380	830	420	1,140	420	1,900	530
February	350	150	600	180	600	380	830	420	1,140	420	1,900	530
March	250	100	350	100	300	200	400	200	600	220	1,000	260
April	100	30	160	40	130	50	240	60	180	70	300	80
May	100	50	170	60	140	50	240	70	190	70	300	90
June	200	70	330	90	270	100	470	130	370	140	620	170
July	200	70	330	90	270	100	470	130	370	140	620	170
August	200	70	330	90	270	100	470	130	370	140	620	170
September	200	70	330	90	270	100	470	130	370	140	620	170
October	100	30	160	40	130	50	240	60	180	70	300	90
November	100	30	160	40	130	50	240	60	180	70	300	90
December	350	150	600	180	600	380	830	420	1,140	420	1,900	530

considering the Red River and the Sheyenne River, supplemental flow needs were obtained as illustrated in figure R-4. The cost of providing sufficient flows to permit a nominal secondary degree of treatment is $86,000, which may result in a conservative annual monetary benefit of $247,000. Similarly, flows which would require only primary treatment would cost $224,000 and result in a benefit of $740,000. Even if transmission and other losses, which have been neglected, were included, it would still appear to be economically feasible to import water to provide a reduced degree of sewage treatment or to permit increased use of waters by other industries and communities.

The above benefits are based upon reasonable existing water uses, and have not considered future developments. Table R-19 shows possible future ultimate flow needs based upon a 45 percent primary waste treatment and 85 percent secondary waste treatment with future population estimates. It was assumed that the present pollution load would double in the 30 intervening years, and that improved sewage treatment methods, facilities, and operation would provide increased treatment efficiencies. A 10 percent increase in efficiency of secondary treatment (75 to 85 percent B.O.D. removal) with adequate plant capacity would handle a 100 percent increase in loading with minor increases in needed stream dilution flows. However, it is wise to defer future evaluations until such time when flow routing is firm and population trends as implemented by the development program may be established.

It is not possible in a report of this type to cover adequately all detailed phases of the many pollutional problems. In certain cases more study may be indicated. In some instances large increases in populations at metropolitan centers, new industry, or expansion of existing industry will necessitate revisions of specified flows or sewage treatment needs.

APPENDIXES

TABLE OF CONTENTS

Appendix		Page
A	Memorandum of Understanding Respecting Joint Program for Public Health Investigations of the Souris-Red River of the North Basins	191
B	Suggested State Water Pollution Control Act . . .	194
C	Partial Review of Literature on Public Health Aspects of Irrigation with Sewage Polluted Water	212
D	Nitrites and Nitrates in Water Supplies	219
E	Limnological Features of the Red River of the North	223
F	Summary of Individual Results	235
G	Laboratory Tests and their Significance	252
H	Definition of Terms	254

Preceding page blank

APPENDIX A

MEMORANDUM OF UNDERSTANDING RESPECTING JOINT PROGRAM FOR PUBLIC HEALTH INVESTIGATIONS OF THE SOURIS-RED RIVER OF THE NORTH BASINS

1. AUTHORITY - THIS MEMORANDUM OF UNDERSTANDING, made and entered into this 20th day of March, 1950, in pursuance of the Act of Congress approved June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto, all of which acts are commonly known and referred to as the Reclamation Laws, particularly the Act of Congress approved August 4, 1939 (53 Stat. 1187), and the Act of Congress approved December 22, 1944 (58 Stat. 887), as amended; and the Act of Congress approved October 12, 1949 (Public Law 350, 81st Congress), designated Interior Department Appropriation Act, 1950, by and between the BUREAU OF RECLAMATION and the PUBLIC HEALTH SERVICE.

2. PURPOSE--The Bureau of Reclamation is now engaged in comprehensive development of the Missouri River Basin Project. In this connection, it is necessary to conduct public health studies in the Souris-Red River of the North Basins to secure data for use in providing for maximum water utilization as a part of the Missouri River Basin Project. This work is recognized as being significant and pertinent to the over-all Basin program and as such it is deemed the responsibility of the Bureau of Reclamation to assure its accomplishment. The work will include determinations of public health benefits from water releases and will pertain to uses of stored water for public health purposes, giving due recognition to potential revenues therefrom. The boundaries of the area covered by this memorandum embrace that area from the eastern boundary of the Milk River drainage basin on the west up to and including the drainage basin of the Red River of the North on the east.

3. SCOPE--Such studies shall include: (a) the extent, types, and major sources of pollution; (b) a review of existing laws and pending legislation regarding pollution of public waters in the States of Montana, North Dakota, and Minnesota; (c) minimum stream flows necessary for public water supplies and other miscellaneous purposes, and for sanitation purposes as related to present and possible future pollution; (d) quality of water for municipal requirements and other miscellaneous purposes; (e) public health benefits of water pollution abatement resulting from the conservation, regulation, and use of water supplies under the Missouri River Basin program; (f) recommendations for pollution abatement and existing plans therefor; (g) effect of current and possible future pollution on water to be used for irrigation; and (h) other public health considerations of the water development program in the Basin.

4. RESPONSIBILITY--The conducting of such public health studies is recognized to be within the scope of the responsibilities of the Public Health Service. As a result, the Public Health Service is hereby requested to make such necessary studies, which studies shall

Preceding page blank

begin as soon as practicable after the first day of the month following the date of execution of this memorandum. Funds have not been made available to the Public Health Service during the current fiscal year for such work, yet the need therefor is immediate.

In consideration of the premises and the mutually dependent promise of the parties hereto, it is agreed as follows:

(a) The Public Health Service will conduct the agreed-upon public health studies of the Souris-Red River of the North Basins. Priority shall be accorded work pertaining to the Souris Basin. The Public Health Service shall assume full responsibility for the preparation of complete reports thereon. Each report, including findings, conclusions, and recommendations, will be submitted in preliminary draft for review and comment by the Bureau of Reclamation, the Fish and Wildlife Service, and the National Park Service as soon as practicable after the completion of pertinent field work. In addition thereto, the Public Health Service will consult and work with public health officials of the States of Montana, North Dakota, and Minnesota relative to pollution and other public health problems as involved in the area, and copies of the preliminary and final reports made by the Public Health Service will be furnished to these State officials for review and comment. Interim reports based upon field evaluations will be submitted not later than June 30, 1950, and final comprehensive reports will be completed not later than April 1, 1951. The Public Health Service will in the future keep abreast of the water resource development program in the area covered by this memorandum and will continue to advise the Bureau of Reclamation on the public health aspects therein. Fifty copies of each such draft will be submitted to the Bureau of Reclamation for distribution and use.

(b) In connection with the studies contemplated herein, the Public Health Service, cooperatively with the several State Health Departments, will furnish personnel and equipment as necessary.

(c) The Bureau of Reclamation shall pay, in advance, the sum of Fifteen Thousand Dollars ($15,000.00) to the Public Health Service for providing the studies, reports, and advice herein referred to. However, should the actual costs incurred by the Public Health Service be less than such sum, any unexpended or unobligated balance shall be returned to the Bureau of Reclamation in accordance with established fiscal procedure. Transfer of funds will be made by the Bureau of Reclamation in pursuance of the Act of Congress approved June 30, 1932 /Sec. 601/ (47 Stat. 417, 418) known as the Economy Act, as amended. The said sum of Fifteen Thousand Dollars ($15,000.00) has been prevalidated, as evidenced by teletype BM-BL 72, dated March 17, 1950, from the District Manager, Bismarck, North Dakota, to the Regional Director, Billings, Montana, attention: 6-305 and pursuant to the instructions contained in teletype W-BL 170 dated March 10, 1950, from Kenneth Markwell, Acting Commissioner of the Bureau of Reclamation to the Regional Director, Billings, Montana, attention: 6-305, and the appropriation "14X0650.001 Missouri River Basin (Reimbursable)," will be charged with such sum. The Public Health Service shall, at appropriate times, furnish the Bureau of Reclamation with statements of expenditures relating to the actual costs incurred by it in the performance of the services herein provided for, it being understood that in no event shall the liability of the Bureau of Reclamation hereunder exceed the said sum of Fifteen Thousand Dollars ($15,000.00).

(d) The Bureau of Reclamation shall furnish for the use of the Public Health Service in connection with the work as outlined such of the following, as may be required:

(1) Limited drafting assistance by the regular staff as can be made available and as time permits.

(2) Maps, charts, hydrologic and other available data.

IN WITNESS WHEREOF, the parties hereto have caused these presents to be executed in duplicate the day and year first above written.

BUREAU OF RECLAMATION	PUBLIC HEALTH SERVICE
By /s/	By /s/
Geo. O. Pratt Acting Regional Director Region 6 Billings, Montana	Glen J. Hopkins Officer in Charge Div. of Water Pollution Control Missouri Drainage Basin Kansas City, Missouri
Date March 20, 1950	Date April 3, 1950

APPENDIX B

SUGGESTED STATE WATER POLLUTION CONTROL ACT*

EXPLANATORY STATEMENT

Increasing interest in development and conservation of our country's water resources has been reflected in the concern which legislatures have shown with the problem of water pollution. Within the last decade more than half the States have adopted new legislation in this field or strengthened existing laws, and in 1948 the Congress passed the Water Pollution Control Act, the first attempt by the Federal Government to join with the States in a comprehensive attack on the problem as a whole. A "Suggested State Water Pollution Control Act" has been prepared as a part of this effort.

The underlying concept and purpose of this legislation is to facilitate interstate cooperation for a more concerted attack on water pollution. Many benefits would be derived if the States adopted legislation uniform in basic principles. It is not expected that the States will repeal their existing legislation and adopt this suggested law. The process of obtaining uniformity is one of evolution. It is suggested that the States take a realistic look at their basic statutes in the field of water pollution control and compare them with the suggested law. Those familiar with State law in this field will find little that is new in the suggested draft. Basically, what has been done has been to adopt the best practices from existing State statutes and using these as a framework to develop a statute that could aid and strengthen the State programs.

A preliminary draft of the "Suggested Act" was submitted for comment to a large number of State sanitary engineers; lawyers; conservationists; industrialists; sportsmen's, wildlife and conservation, agricultural and recreational groups; national lay organizations; municipal organizations; and other persons interested in this field. Subsequently, the preliminary draft, together with comment which was received from all parts of the country, was considered and discussed by a board of expert consultants meeting in Washington. The "Suggested Act" was prepared and revised in light of comments and suggestions resulting from the foregoing procedures.

State water pollution control legislation developed traditionally out of the authority of health departments to preserve public health. In conjunction with this there was piecemeal lodging of concurrent water pollution control authority in several other departments of State governments such as those dealing with agriculture, fish and wildlife, and mines and minerals which also had an interest in water pollution control. The modern approach to the problem is reflected in recent State statutes whose object is to preserve and improve water quality for all legitimate uses and do this through an agency that represents all affected interests in the State. Accompanying this has been a shifting emphasis from the mere abatement of existing pollution to the policy of preventing pollution in its incipiency.

---

*The "Suggested State Water Pollution Control Act" has been endorsed by the Council of State Governments and recommended to the States in the Council's "Suggested State Legislation; Program for 1951" issued in November, 1950.

In the early statutes the administrative approach was largely negative in character. That is, when a particular action was found to cause pollution the administrative agency was authorized to take steps to abate such pollution. The Suggested State Water Pollution Control Act follows the more recent statutes by authorizing the agency to develop a comprehensive program to deal with the problem in all waters of the State. Under this approach, the agency, having determined permissive limits of waste discharges into the waters of the State, uses its enforcement procedure to abate existing pollution and restore the quality of polluted waters, while through a system of permits it prevents any increase in waste discharges which would impair desired water uses.

The Act is designed to give the agency broad discretion in administration of the program and makes its jurisdiction complete over all waters of the State. It avoids such restrictive practices as exemption of particular industries or geographic areas and legislative classification of particular streams for specified water uses.

While the Act is complete in itself, it rests on a framework of other State statutory and constitutional provisions. Perhaps one of the most important of these relates to municipal financing. No water pollution control program can operate successfully unless the State and its political subdivisions can finance the construction and operation of remedial works for treatment of wastes. The Suggested State Water Pollution Control Act does not treat this subject in view of its complexity and the numerous individual problems peculiar to particular States. Reference is made to the Council of State Government's 1949 program of suggested State legislation for a general approach to the problem and suggestions for individual States.

While a section-by-section analysis of the Act will not be attempted, some comments may be directed to its principal features.

Pollution - The most important definition in the Act is the definition of "pollution," which is designed to protect all legitimate uses of waters of the State. To this end, "pollution" as defined includes both discharges of wastes actually or potentially harmful to such uses and also altering the properties of the waters in such a way as to be harmful. The latter, for example, would cover heating of water in such a way as to deplete oxygen supply and reduce the capacity of the water to support fish life or stabilize discharges of wastes. This definition must be read together with subsequent sections of the Act authorizing the classification of waters and the setting of standards of water quality. Discharges which violate such standards and classifications are declared unlawful, but discharges consistent with them are not considered "pollution" for purposes of the Act. The Act, therefore, gives effect to the agency's action in classifying waters and setting standards but does not hold its enforcement powers in abeyance until such action can be completed.

Type of Administrative Agency - One of the most important questions for any State to decide in preparing water pollution control legislation is the agency to which enforcement of the program will be entrusted. As has been said, most early legislation of this type vested authority in the State health department. The problems of water pollution control, however, concern other interests than health, and in a broader sense are an integral part of the problem of preserving the water resources of the State. For example, wildlife and conservation interests, industry, municipalities and agriculture have a stake in the enforcement of a water pollution control program. It is believed important that any agency which is set up to administer such a program should be so constituted as to take into account the interests and views of these and other affected groups in addition to health considerations.

Most States which have recently enacted water pollution control legislation have entrusted its enforcement to a board representative of the interests considered to be affected. Such boards are sometimes made up of representatives of various departments of the State government, sometimes of citizens from outside the government, and more frequently of a combination of the two. Adoption of this form has the advantage of facilitating representation of affected interests in the agency. If it is adopted, provision should also be made for an executive secretary to serve as the administrator of the program and to carry out the policies adopted by the board. Some States may wish to vest responsibility for the program in a single administrator. If this is done, it would seem advisable to secure representation of affected interests through an advisory council, and it may also be considered desirable to set up a board of review to hear appeals from the single administrator's decisions.

The Suggested State Water Pollution Control Act has incorporated alternative provisions covering both the board and the single administrator type of agency.

States adopting water pollution control legislation recently have in some cases set up completely independent agencies, but have more frequently placed the agency within an existing State department, generally the department of health. This is a matter for determination by each individual State. Where the agency is set up within an existing State department, however, it is believed desirable to vest it with authority to act independently since an agency representing so broad a field of the State interests should not be subjected to the supervisory control of any single State department which operates in a comparatively narrower field.

Where the agency is established in an existing State department it is recommended that it be placed in the State health department. Not only is health a major public interest and an integral part of an active water pollution control program, but also the health department usually has trained personnel and facilities which may be utilized for work in connection with the water pollution control program. It will usually be true that the health department is already carrying on some of the functions which this Act vests in the new agency. Use of health department personnel and facilities therefore will avoid unnecessary duplication of functions.

Classification of Waters -- Standards of Water Quality - Some agencies in the administration of water pollution control programs have classified the waters of the State according to their use and have established standards of quality for such waters in accordance with their respective uses. Proponents of this method have urged that classification and setting of standards is an essential element of any comprehensive program and also that no enforcement action can be undertaken without determination of the use to which a particular body of water should be put and the degree of quality which the water must have in order to be suitable for such use. This approach, however, has been severely criticized by others who maintain that the process is administratively difficult and time consuming, that classifications once made are hard to change and tend to create vested interests, and that the tendency will be to reduce waters to the level of mere carriers of wastes because of the pressure of special interests.

The Suggested State Water Pollution Control Act authorizes the agency to classify waters and set up standards of quality for water falling within particular classifications but does not make it mandatory to do so. Classifications and standards once promulgated have a definite legal effect and their violation is made unlawful; conversely, discharges which comply with such classifications and standards are not pollution within the meaning of this Act. In view of the number of persons affected by classifications and standards, it is required that their adoption be preceded by a public hearing open to all residents of the areas affected, and that adequate notice thereof be given. The Act provides that in classifying waters and setting standards the agency will be guided by the principal of constantly seeking to improve water quality and upgrading streams for progressively higher uses to the maximum extent practicable.

Permits - Potentially one of the most effective techniques for control of water pollution is a permit system, under which discharges of wastes into any waters of the State are prohibited except as permitted by the agency after examination of plans, specifications and other data. Through this means the agency can either prohibit discharges altogether or condition their approval on treatment adequate to protect legitimate water uses. The Act contains broad provisions authorizing the agency to require permits for waste discharges and additions to plants which would result in increased pollution. Normally, the permit system would be restricted to new pollution or increases in existing waste discharges, but the breadth of the language employed is sufficient to enable the agency to extend the requirement to existing discharges where this is considered desirable administratively.

Enforcement - The Act affords a variety of methods for proceeding against any alleged polluter. It is made unlawful to cause any pollution of the waters of the State or to violate any order issued by the agency, including an order establishing a classification of waters or standards of water quality. Pollution of waters of the State is declared to be a public nuisance and is therefore subject to abatement in accordance with State practice for abatement of nuisances. Violation of the provisions of the Act or any order or determination by the agency or failure to perform any duty imposed by the Act is declared to be a misdemeanor. In addition, the Attorney General has the duty to bring an action for an injunction against any person violating any provision of the Act or any order of the agency. The principal method of making the program effective through compulsory process, however, is by administrative action. The agency is empowered to issue orders against alleged polluters after adequate opportunity for hearing. Such orders if not appealed to the courts become final and are enforceable in much the same way as the judgment of a court. The same administrative hearing procedure is employed in cases of revocation, denial or modification of permits.

Appeals may be taken to the courts from orders of the agency. Such appeals do not involve trial de novo but are primarily reviews of the legal propriety of the agency's decision. If the prescribed statutory procedure has been followed and the determination is supported by substantial evidence, the order of the agency will be affirmed by the court.

It is recognized that the provisions of the Act for administrative hearings and judicial review will not be appropriate in all cases. Each State will necessarily adapt them to their own administrative and judicial practice and existing statutes. The provisions of the Act, however, embody principles which are believed desirable in this type of legislation.

Administrative Powers - The Act confers on the agency the requisite administrative powers to carry out its responsibilities. Thus, the agency is empowered to hold hearings, subpoena witnesses, enforce its subpoenas, administer oaths, examine plans and specifications, require the keeping of records and the making of reports, and enter on property at reasonable times for purposes of inspection and investigation.

SUGGESTED STATE WATER POLLUTION CONTROL ACT

(Title. It should conform to State requirements. The following is a suggestion; a more complete title should be used where necessary.)

"AN ACT to establish a State water pollution control agency, and to control, prevent and abate pollution of the surface and underground waters of the State."

(Be it enacted, etc.)

Section 1. Statement of Policy.[1] Whereas the pollution of the waters of this State constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life, and impairs domestic, agricultural, industrial,[2] recreational and other legitimate beneficial uses of water, and whereas the problem of water pollution in this State is closely related to the problem of water pollution in adjoining States, it is hereby declared to be the public policy of this State to conserve the waters of the State and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the State without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; and to cooperate with other agencies of the State, agencies of other States and the Federal Government in carrying out these objectives.

Section 2. Definitions. For the purposes of this Act, the following words and phrases shall have the meanings ascribed to them in this section.

(a) "Pollution" means such contamination, or other alteration of the physical, chemical or biological properties, of any waters of the State, or such discharge of any liquid, gaseous or solid substance into any waters of the State as will or is likely to create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

---

[1] Where a State has committed itself to a general water resources program, a declaration to the effect that water pollution control is an integral part of such program should be added. States in the West and Southwest may want to add a statement to the effect that water pollution control is basically a water conservation program in their States.

[2] Specific wastes which are of particular interest to an individual State may be included, such as mine wastes, etc.

(b) "Wastes" means sewage, industrial waste and all other liquid, gaseous or solid substances which may pollute or tend to pollute any waters of the State.

(c) "Sewerage system" means pipe lines or conduits, pumping stations, and force mains, and all other constructions, devices, appurtenances and facilities used for collecting or conducting wastes to a point of ultimate disposal.

(d) "Treatment Works" means any plant, disposal field, lagoon, dam, pumping station, incinerator, or other works used for the purpose of treating, stabilizing or holding wastes.

(e) "Disposal system" means a system for disposing of wastes, and includes sewerage systems and treatment works.

(f) "Waters of the State" means all streams,[3] lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon this State or any portion thereof.

(g) "Person" means the State, any municipality, political subdivision, institution, public or private corporation, individual, partnership, or other entity.

Section 3. Creation and Organization of Board; Meetings; Employees. There is hereby created and established[4] a State water pollution control board hereinafter referred to as the "Board" which shall be composed of _____ members as follows: The Director of the Department of Health; the Director of the Department of Agriculture; the Director of the Department of Conservation, Fish and Game; and two members appointed for terms of ______years by the Governor. One of the members appointed by the Governor shall be experienced in the field of municipal government and one shall be experienced in the field of industrial activities.[5] The Board is directed to carry out the functions and duties conferred on it by this Act.

---

[3] Seaboard States should include within this definition such coastal waters as are within the jurisdiction of the State.

[4] The State water pollution control authority may be set up as an independent board or may be established within an existing State department. Regardless of where the Board is placed, it is important that the statutory authority flow directly to it and that it have independent powers of operation.

In cases where the Board is placed in an existing State department, it is suggested that it be placed within the State health department because of the close connection between the work of the State health department and water pollution control activities. Further, State health departments in most cases are already active in the field of water pollution control and have trained technical staffs working on pollution control problems.

The "Suggested State Water Pollution Control Act" may be adapted to the placing of water pollution control authority within the State health department by inserting the words "in the State health department" after the word "established"; virtually no other change will be necessary.

Each ex-officio member of the Board may, by official order filed in his respective department, designate a deputy in his department to perform the duties of the member making the designation. Such persons, if any, designated pursuant to this section, shall have the powers and be subject to the duties and responsibilities of the officer appointing him.[6]

No additional compensation shall be allowed any member of the Board[7] for services rendered in that capacity. Actual and necessary travel and other expenses incurred by members in the discharge of their official duties as members of the Board shall be paid out of any funds which are or may become available for the purposes of this Act.

The Board shall organize and annually select one of its members to serve as chairman and one of its members to serve as vice-chairman, shall hold at least four regular meetings each calendar year and shall keep a record of its proceedings which shall be open to the public for inspection. Special meetings may be called by the chairman, and must be called by him upon receipt of a written request therefor signed by two or more members of the Board. Written notice of the time and place of each meeting shall be delivered to the office of each member of the Board and the executive secretary. A majority of the members of the Board shall constitute a quorum.

---

[5] This list of members of the Board is suggestive only and is not meant to be inclusive. The membership of the Board will necessarily vary from State to State. In addition to those mentioned above, some States may desire to place members on the Board for specified terms who are representatives of such fields as public affairs, recreational and resort interests, and broad water resources activities.

[6] It may be necessary in some States also to provide that: "Such designation shall be deemed temporary only and shall not affect the civil service or retirement rights of any person so designated."

[7] In States where it is customary to provide an honorarium for members of State Boards and Commissions, similar allowances should be made for those members of the State water pollution control board who are not serving in an ex-officio capacity.

The Board shall appoint an executive secretary[8] who shall direct and carry out all water pollution control activities vested in the Board. Such executive secretary shall be a person fully trained and experienced in the field of water pollution control and if the Board so desires, may be a present employee of the State government. The executive secretary in the interim between meetings of the Board shall have authority to perform in the name of the Board all functions and duties of the Board except the authority to adopt and promulgate standards, rules and regulations; classify streams; revoke permits; and issue or modify orders.

The Board may employ, compensate, and prescribe the powers and duties of such officers, employees, and consultants, in accordance with the laws of this State, as may be necessary to carry out the provisions of this Act. However, technical, legal or other services shall be performed, insofar as practicable, by personnel of the department of health and by other State departments, agencies, and offices.

The Board may delegate to the executive secretary, officers, employees, and consultants of the Board such functions and duties as are vested in the Board by this Act, except the authority to adopt and promulgate standards, rules and regulations; classify waters; revoke permits; and issue or modify orders.

((Alternate Section 3))

Section 3. Creation and Organization of Agency and Advisory Board; Meetings, Employees. (a) There is hereby created and established [9] a State water pollution control agency [10], hereinafter referred to as the "Agency."

---

[8] It may be necessary to include a statutory provision for the salary of the executive secretary, if the State statutes do not provide an overall compensation system for State officials.

[9] The State water pollution control authority may be set up as an independent Agency or may be established within an existing State department. Regardless of where the Agency is placed, it is important that the statutory authority flow directly to it and that it have independent powers of operation.

In cases where the Agency is placed within an existing State department, it is suggested that it be placed within the State health department because of the close connection between the work of the State health department and water pollution control activities. Further, State health departments, in most cases, are already active in the field of water pollution control and have trained technical staffs working on the problem.

The "Suggested State Water Pollution Control Act" may be adapted to the placing of water pollution control authority within the State health department by inserting the words "in the State health department" after the word "established"; virtually no other change will be necessary

[10] It may be desirable to modify this type of Agency by making provision for a Review Board to review the final orders of the single administrator.

(b) The Governor shall appoint an administrator who shall be the head of the Agency, shall perform all functions and duties given to the Agency under this Act, and shall direct and carry out all water pollution control activities vested in the Agency.[11] Such administrator shall be a person fully trained and experienced in the field of water pollution control and if the Agency so desires may be a present employee of the State government.

(c) The Agency may employ, compensate, and prescribe the powers and duties of such officers, employees, and consultants in accordance with the laws of the State as may be necessary to carry out the provisions of this Act. However, technical, legal or other services shall be performed, insofar as practicable, by personnel of the department of health and by other State departments, agencies, and offices.

(d) The Administrator may delegate to the executive secretary, officers, employees, and consultants of the Agency such functions and duties as are vested in the Agency by this Act, except the authority to adopt and promulgate standards, rules and regulations; classify waters; revoke permits, and issue or modify orders.

(e) There is hereby established within the Agency a State Water Pollution Control Advisory Board consisting of ____ members. Such members are to be appointed by the Governor for terms of ____ years or until successors shall be appointed or qualified,[12] and shall consist of the Administrator of the State water pollution control agency who shall be chairman, and persons experienced in the fields of public health; agriculture; conservation, fish and wildlife; political subdivisions; and industrial activities.[13] The Water Pollution Control Advisory Board shall hold at least two regular meetings each calendar year. It shall be the duty of the Board to review the policies and program of the State water pollution control agency as developed under authority of this Act and to make recommendations thereon to the Administrator of the Agency.

No compensation shall be allowed any members of the Board[14] for services rendered in that capacity; however, actual and necessary travel and other expenses incurred by members in the discharge of their official duties as members of the Agency shall be paid out of any funds which are or may become available for the purposes of this Act.

---

[11] It may be necessary to include a statutory provision for the salary of the administrator, if the State statutes do not provide an overall compensation system for State officials.

[12] Provision should be made for overlapping terms of office for the members of the Advisory Board.

[13] This list of members of the Advisory Board is suggestive only and is not to be deemed to be inclusive. The membership of the Board will necessarily vary from State to State and may include ex-officio members.

[14] In States where it is customary to provide an honorarium for members of State Boards and Commissions, similar allowances should be made for those members of the State Water Pollution Control Advisory Board who are not serving in an ex-officio capacity.

Section 4. Powers and Duties. The Board[15] shall have and may exercise the following powers and duties:

(a) To develop comprehensive programs for the prevention, control and abatement of new or existing pollution of the waters of the State;

(b) To advise, consult, and cooperate with other agencies of the State, the Federal Government, other States and interstate agencies, and with affected groups, political subdivisions, and industries in furtherance of the purposes of this Act;

(c) To accept and administer loans and grants from the Federal Government and from other sources, public or private, for carrying out any of its functions;

(d) To encourage, participate in, or conduct studies, investigations, research and demonstrations relating to water pollution and causes, prevention, control, and abatement thereof as it may deem advisable and necessary for the discharge of its duties under this Act;

(e) To collect and disseminate information relating to water pollution and the prevention, control and abatement thereof;

(f) To adopt, modify or repeal and promulgate standards of quality of the waters of the State and classify such waters according to their best uses in the interest of the public under such conditions as the Board may prescribe for the prevention, control and abatement of pollution;

(g) To adopt, modify, repeal, promulgate and enforce rules and regulations implementing or effectuating the powers and duties of the Board under this Act;

(h) To issue, modify or revoke orders (1) prohibiting or abating discharges of wastes into the waters of the State; (2) requiring the construction of new disposal systems or any parts thereof or the modification, extension or alteration of existing disposal systems or any parts thereof, or the adoption of other remedial measures to prevent, control or abate pollution; and

---

[15] The word "Board" is used throughout subsequent sections of the Act. Where alternate section 3 is selected, the word "Board" should be changed to "Agency."

(3) setting standards of water quality, classifying waters or evidencing any other determination by the Board under this Act;

(i) To review plans, specifications or other data relative to disposal systems or any part thereof in connection with the issuance of such permits as are required by this Act;

(j) To issue, continue in effect, revoke, modify or deny, under such conditions as it may prescribe, to prevent, control or abate pollution, permits for the discharge of wastes into the waters of the State, and for the installation, modification or operation of disposal systems or any parts thereof;

(k) To exercise all incidental powers necessary to carry out the purposes of this Act.

Section 5. Prohibitions. (a) It shall be unlawful for any person to cause pollution as defined in section 2 (a) of this Act of any waters of the State or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any waters of the State. Any such action is hereby declared to be a public nuisance.

(b) It shall be unlawful for any person to carry on any of the following activities without first securing such permit[16] from the Board, as is required by it, for the disposal of all wastes which are or may be discharged thereby into the waters of the State: (1) the construction, installation, modification or operation of any disposal system or part thereof or any extension or addition thereto; (2) the increase in volume or strength of any wastes in excess of the permissive discharges specified under any existing permit; (3) the construction, installation, or operation of any industrial or commercial establishment[17] or any extension or modification thereof or addition thereto, the operation of which would cause an increase in the discharge of wastes into the waters of the State or would otherwise alter the physical, chemical or biological properties of any waters of the State in any manner not already lawfully authorized; (4) the construction or use of any new outlet for the discharge of any wastes into the waters of the State.

The Board under such conditions as it may prescribe, may require the submission of such plans, specifications and other information as it deems relevant in connection with the issuance of such permits.

Section 6. Classification of Waters; Standards of Water Quality. (a) In order to effectuate a comprehensive program for the prevention, control and abatement of pollution of the waters of the State, the Board is authorized to group such waters into classes according to their present and future best uses for the purpose of progressively improving the quality of such waters and upgrading them from time to time by reclassifying them, to the maximum extent that is practical and in the public interest. Standards of quality for each such classification consistent with best present and future use of such waters may be adopted by the Board and from time to time modified or changed.[18]

---

[16] Some States may wish to validate by statute permits or approval of plans and specifications presently in effect which have been issued by competent State authorities such as the department of health.

[17] Western and Southwestern States should include construction, installation, modification or operation of irrigation projects.

(b) Prior to classifying waters or setting standards or modifying or repealing such classifications or standards the Board shall conduct public hearings in connection therewith. Notice of public hearing for the consideration, adoption or amendment of the classification of waters and standards of purity and quality thereof shall specify the waters concerning which a classification is sought to be made or for which standards are sought to be adopted and the time, date, and place of such hearing. Such notice shall be published at least twice in a newspaper of general circulation in the area affected and shall be mailed at least twenty days before such public hearing to the chief executive of each political subdivision of the area affected and may be mailed to such other persons as the Board has reason to believe may be affected by such classification and the setting of such standards.

(c) The adoption of standards of quality of the waters of the State and classification of such waters or any modification or change thereof shall be effectuated by an order of the Board which shall be published in a newspaper of general circulation in the area affected. In classifying waters and setting standards of water quality or making any modification or change thereof, the Board shall announce a reasonable time for persons discharging wastes into the waters of the State to comply with such classification or standards, unless such discharges create an actual or potential hazard to public health.

Any discharge in accord with such classification or standards shall not be deemed to be pollution for the purposes of this Act.

Section 7. Proceedings before Board. (a) Whenever the Board determines there are reasonable grounds to believe that there has been a violation of any of the provisions of this Act or of any order of the Board, it may give written notice to the alleged violator or violators specifying the causes of complaint. Such notice shall require that the matters complained of be corrected or that the alleged violator appear before the Board at a time and place specified in the notice and answer the charges complained of. The notice shall be delivered to the alleged violator or violators in accordance with the provisions of subsection (e) of this section not less than ___ days before the time set for the hearing.

(b) The Board shall afford an opportunity for a fair hearing in accordance with the provisions of section 8 to the alleged violator or violators at the time and place specified in the notice or any modification thereof. On the basis of the evidence produced at the hearing the Board shall make findings of fact and conclusions of law and enter such order as in its opinion will best further the purposes of this Act and shall give written notice of such order to the alleged violator and to such other persons as shall have appeared at the hearing and made written request for notice of the order. If the hearing is held before any person other than the Board itself, such person shall transmit the record of the hearing together with recommendations for findings of fact and conclusions of law to the Board which shall thereupon enter its order on the basis of such record and recommendations. The order of the Board shall become final and binding on all parties unless appealed to the courts as provided in section 11 within _______ days after notice has been sent to the parties.

---

[18] States which adhere to the "prior acquisition doctrine" should take cognizance of the effect that classification will have on water rights established under other laws.

(c) Any person who is denied a permit by the Board or who has such permit revoked or modified shall be afforded an opportunity for a hearing in connection therewith upon written application within ______ days after receipt of notice from the Board of such denial, revocation or modification.

(d) Whenever the Board finds that an emergency exists requiring immediate action to protect the public health or welfare, it may without notice or hearing issue an order reciting the existence of such an emergency and requiring that such action be taken as it deems necessary to meet the emergency. Notwithstanding the provisions of subsection (b) of this section such order shall be effective immediately. Any person to whom such order is directed shall comply therewith immediately but on application to the Board shall be afforded a hearing as soon as possible. On the basis of such hearing the Board shall continue such order in effect, revoke it or modify it.

(e) Except as otherwise expressly provided, any notice, order, or other instrument issued by or under authority of the Board may be served on any person affected thereby personally or by publication, and proof of such service may be made in like manner as in case of service of a summons in a civil action, such proof to be filed in the office of the Board; or such service may be made by mailing a copy of the notice, order, or other instrument by registered mail, directed to the person affected at his last known post office address as shown by the files or records of the Board, and proof thereof may be made by the affidavit of the person who did the mailing, filed in the office of the Board.

Every certificate or affidavit of service made and filed as herein provided shall be prima facie evidence of the facts therein stated, and a certified copy thereof shall have like force and effect.[19]

---

[19] Where not otherwise covered by general provisions of State statutes applicable to all administrative agencies, consideration should be given to covering the following points in the "Suggested Act":
(1) Filing or recording the regulations and orders of the State agency with a designated official;
(2) Making such filing and recording prima facie evidence that all requirements of law have been complied with;
(3) Requiring all courts to take judicial notice of regulations and orders when filed or recorded as prescribed;
(4) Certifying copies.

Section 8. Hearings. The hearings herein provided may be conducted by the Board itself at a regular or special meeting of the Board, or the Board may designate hearing officers who shall have the power and authority to conduct such hearings in the name of the Board at any time and place. A record or summary of the proceedings of such hearings shall be taken and filed with the Board, together with findings of fact and conclusions of law made by the Board. In any such hearing a member of the Board or a hearing officer designated by it shall have the power to administer oaths, examine witnesses and issue in the name of the Board notice of the hearings or subpoenas requiring the testimony of witnesses and the production of evidence relevant to any matter involved in such hearing. Witnesses who are subpoenaed shall receive the same fees and mileage as in civil actions. In case of contumacy or refusal to obey a notice of hearing or subpoena issued under this section, the _______ court shall have jurisdiction upon application of the Board or its representative, to issue an order requiring such person to appear and testify or produce evidence as the case may require and any failure to obey such order of the court may be punished by such court as contempt thereof.

Section 9. Inspections and Investigations; Maintenance of Records. The Board or its duly authorized representative shall have the power to enter at reasonable times upon any private or public property for the purpose of inspecting and investigating conditions relating to pollution or the possible pollution of any waters of the State.

Any authorized representative of the Board may examine any records or memoranda pertaining to the operation of disposal systems. The Board may require the maintenance of records relating to the operation of disposal systems. Copies of such records must be submitted to the Board on request.

Section 10. Penalties;[20] Injunctions. (a) Any person [21] who shall violate any of the provisions of, or who fails to perform any duty imposed by, this Act or who violates any order or determination of the Board promulgated pursuant to this Act shall be guilty

---

[20] A number of States provide by statute for penalties, additional to those outlined in section 10, for persons killing fish by polluting the waters of the State. Such a provision appears logical and desirable, since the pollution has, in effect, destroyed property of the State and the person responsible should be liable to pay damages therefor. Such provision has not been included in this "Suggested Act", however, since it is considered more appropriate for inclusion in the conservation laws of the State. If the State wishes to include it in this Act, the following language may be employed:

> "(c) Any person who violates any of the provisions of, or fails to perform any duty imposed by, this Act, or who violates an order or other determination of the Board promulgated pursuant to this Act, and causes the death of fish or other wildlife shall, in addition to the penalties provided in subsections (a) and (b) be liable to pay to the State an additional amount

of a misdemeanor[22] and in addition thereto may be enjoined from continuing such violation. Each day upon which such violation occurs shall constitute a separate violation.

(b) It shall be the duty of the Attorney General on the request of the Board to bring an action for an injunction against any person violating the provisions of this Act, or violating any order or determination of the Board. In any action for an injunction brought pursuant to this section, any finding of the Board after hearing or due notice shall be prima facie evidence of the fact or facts found therein.

Section 11. Review.[23] (a) An appeal may be taken from any final order or other final determination of the Board, by any person who is or may be adversely affected thereby, or by the Attorney General on behalf of the State to the ______ court of the State of the area

---

[20] (cont'd.) equal to the sum of money reasonably necessary to restock such waters or replenish such wildlife as determined by the Board after consultation with the fish and game commission. Such amount may be recovered by the Board on behalf of the State in a civil action brought in the ______ court."

[21] Where the order is directed against a municipality, the responsible municipal officials would have responsibility for taking steps to comply with it. To enable them to take the necessary action, there must be adequate statutory provision for financing such action by the municipality. Issuance of revenue bonds is a method of financing which has received increasingly broad acceptance in recent years. In those States where such issuance is contingent on a vote of the electors of the municipality, enforcement of the Act would be facilitated by a provision waiving the necessity of such a vote in the case of revenue bonds issued to finance the cost of complying with a final order abating pollution. It is believed that the requirement of such a vote is not appropriate where the legal obligation of the municipality to construct a treatment works or take other remedial action has been established under a statute.

[22] If the penalty provided for misdemeanors by general statutes is considered insufficient, the State may wish to strike out the balance of the sentence after "misdemeanor" and substitute the following:

> "and upon conviction thereof shall be punished by a fine of not more than $______ or by imprisonment for a term of not more than one year or by both such fine and imprisonment. In addition thereto such person may be enjoined from continuing such violation."

[23] The above appeal procedure is suggestive only. In any particular State such procedures will necessarily be adapted to the existing judicial structure and practice.

affected or to the ______ court of (seat of Government). Within 30 days after receipt of a copy of the order, or other final determination, or after service of notice thereof by registered mail, the appellant or his attorney shall serve a notice of appeal on the Agency through its ((executive secretary)) or ((Administrator)) provided that during such 30-day period the court may for good cause shown extend such time for not exceeding an additional 60 days. The notice of appeal shall refer to the action of the Board appealed from, shall specify the grounds of appeal, including both points of law and fact which are asserted or questioned by the appellant. A copy of the original notice of appeal with proof of service shall be filed by the appellant or his attorney with the clerk of the court within ten days of the service of the notice and thereupon the court shall have jurisdiction of the appeal.

(b) The appellant and the Board shall in all cases be deemed the original parties to an appeal. The State through the Attorney General or any other person affected may become a party by intervention as in a civil action upon showing cause therefor. The Attorney General shall represent the Board, if requested, upon all such appeals unless he appeals or intervenes in behalf of the State. If the Attorney General or a member of his staff is not available to represent the Board in any particular proceeding, the Board is empowered to appoint special counsel for such proceeding. No bond or deposit for costs shall be required of the State or Board upon any such appeal or upon any subsequent appeal to the Supreme Court or other court proceedings pertaining to the matter.

(c) The appeal shall be heard and determined by the court upon the issues raised by the notice of appeal and the answer thereto according to the rules related to a trial in the nature of an appeal in equity of an administrative determination. All findings of fact by the Board are to be deemed final, unless it is shown that such findings were not supported by substantial evidence produced before the Board at the hearing. In any appeal or other proceeding involving any order, or other determination of the Board, the action of the Board shall be prima facie reasonable and valid and it shall be presumed that all requirements of the law pertaining to the taking thereof have been complied with. A copy of the proceedings before the Board shall be certified to the Court in connection with each appeal.

(d) A further appeal may be taken to the Supreme Court of the State in the same manner as appeals in equity are taken.

Section 12. Conflicting Laws. This Act shall not be construed as repealing any laws of the State relating to the pollution of waters thereof or any conservation laws, but shall be held and construed as auxiliary and supplementary thereto, except to the extent that the same are in direct conflict herewith.

Section 13. Existing Rights and Remedies Preserved. It is the purpose of this Act to provide additional and cumulative remedies to prevent, abate and control the pollution of the waters of the State. Nothing herein contained shall be construed to abridge or alter rights of action or remedies in equity or under the common law or statutory law, criminal or civil, nor shall any provision of this Act, or any act done by virtue thereof, be construed as estopping the State, or any municipality or person, as riparian owners or otherwise, in the exercise of their rights in equity or under the common law or statutory law to suppress nuisances or to abate pollution.

Section 14. Severability. If any section, subsection, sentence, clause, phrase or words of this Act is for any reason held to be unconstitutional, such decree shall not affect the validity of any remaining portion of this Act.

Section 15. Short Title. This Act may be cited as the (State) Water Pollution Control Act.

NOTE: Where State law or practice requires that an appropriation authorization or an actual appropriation be made with basic legislation, such provisions should be incorporated into the "Suggested Act."

APPENDIX C

PARTIAL REVIEW OF LITERATURE ON PUBLIC HEALTH ASPECTS OF IRRIGATION WITH SEWAGE POLLUTED WATER[1]

1. Davidson (1), according to Wilson (9), reports an outbreak of typhoid and paratyphoid fever involving 65 cases in North Battleford, Saskatchewan, Canada, during the summer of 1941. Neither milk nor water could be incriminated as the agent of transmission. Inconclusive evidence indicated that the infection was spread by vegetables which were irrigated, and possibly washed, with water from a ditch into which the sewage works discharged its effluent.

2. Chapman (2), stresses the need for treatment of sewage discharged to streams from which water is taken to irrigate market produce. Investigations conducted by the Colorado State Board of Health have shown that vegetables, grown in fields many miles below the source of the pollution, contained large numbers of colon bacilli. In many instances washing could not make them fit for human consumption. Some epidemiological evidence is presented. The death rate for typhoid fever, also for diarrhea and enteritis in infants up to 2 years of age, in Colorado is high when compared to that for the U. S. and several western States. Colorado counties having polluted waters have death rates for the above infections almost twice those of counties in which there is little or no pollution of streams. Maps are presented which show the grossly polluted streams are closely associated with the counties having these higher death rates. Water and milk were not considered the infection source. It was recommended that fruits and vegetables grown under or close to the ground should not be irrigated with sewage polluted water. Although cooking may make eating such vegetables safe, it does not eliminate the possibility of introduction of infectious matter into the kitchen and its transfer to foodstuffs.

3. Lumsden and Anderson (3), in their investigation of the origin and prevalence of typhoid fever in the District of Columbia, found (3a) "A suggestively large portion of the typhoid cases in the District of Columbia had eaten lettuce, celery or strawberries during the 30 days prior to illness." They experienced difficulty in tracing the produce back to its source and therefore considered definite conclusions "not justifiable." They conclude (3b), however, that "in view of the insanitary conditions, particularly in respect to the lack of sanitary privies on farms which supply a large portion of the green vegetables and fruits distributed in Washington, it seems quite probable that those foodstuffs play some part, and for occasional periods perhaps a very considerable part, in the distribution of typhoid-fever infection in the District of Columbia." Furthermore, they recommend (3c), "The enactment of legislation prohibiting the sale or the offering for sale in the District of Columbia of . . . any green garden truck obtained from farms not provided with either sanitary privies or sanitary water-closets."

---

[1] Acknowledgment is made of the use of this Review as included in the South Platte River Basin Interim Report and the Kansas River Basin Water Pollution Investigation.

4. Bundesen (4), reports that following a typhoid outbreak in Chicago, which was eventually traced to oyster infection, special effort was made to determine the sources of certain vegetables, lettuce and watercress, served in hotels and restaurants, where it appeared the majority of cases had contracted the infection. This was found to be impossible; there was no common source for such produce. In connection with the investigation bacteriological examination of fruits, vegetables and watercress was undertaken. E.coli bacteria were found but whether of human or other source was not determined. In one case high coli contamination of lettuce was traced to the ice in which it was packed. Need for greater attention to watercress is stressed. In the discussion of Bundesen's paper Dr. F. C. Johnson, a pediatrician, comments that based on his experience he has "advised not to feed lettuce or celery to children as the possibility of infections being carried by these raw vegetables is really great."

5. In the discussion (5) of Dr. Warrys report of an outbreak of enteric disease involving 110 cases in the borough of Hackney, England, it is noted that a high percent of the cases had partaken of watercress within 3 weeks prior to the illness, and bacteriological examination of beds from which the watercress had been taken showed the presence of sewage organisms, in one case, as high as 50 E.coli bacteria per cubic centimeter of water.

6. An article in the Journal American Medical Association (6) notes the raising of vegetables, frequently eaten raw, on the Paris, France, sewage farm and associates the occurrence every year, from July to October, of typhoid fever in Paris with the marketing of these vegetables. "Clauditz found germs, after several days, on green herbs thus treated which a thorough washing could not remove. Dr. E. Marchoux, after an investigation, 'recommended that the kinds of herbs and vegetables that may be grown on sewaged land be established by law.'"

7. The American Society of Civil Engineers' committee on salvage of sewage (7) notes that in 1934 the directors of public health in each of the 48 states and the District of Columbia were asked for information on the extent of sewage use for irrigation. Only 9 states, of the 40 replies received, admitted having experience with sewage irrigation and sewage irrigated crops. Significantly, "four were able to trace illness of an epidemic order to such use, whereas one other stated that cattle, pastured on a raw sewage irrigated field developed poorly and were infested with Cysticercus bovis." At that time (7a) "Only one of the nine was agreeable to the use of (sewage) treatment plant effluent on vegetables to be eaten raw," and that state prescribed practically potable water standards for such effluent. In summarizing the committee states (7b) "Thus it would appear that, except for use upon vegetables to be eaten raw, an effluent from about that afforded by subsidence, trickling filters, and secondary subsidence effecting about 85 percent reduction in biochemical oxygen demand (B.O.D.) and suspended solids, followed by chlorination, should satisfy health requirements..."

8. Roberts (8) noted 23 of 45 cattle fattened on the Tucson, Arizona, sewage farm were upon slaughtering found infested with the tapeworm, Cysticercus bovis. Since these cattle apparently came from different

sources -- they all bore different brands - and such general infestation indicated a source common to all or most of them, it was concluded that the investation resulted from drinking sewage polluted water.

9. Wilson (9) cites the experience at the Melbourne, Australia, sewage farm where in 1937, 46 percent of the cattle grazed were found infested with Taenia saginata. The sale of these cattle was banned. During a six month survey of Melbourne (1941-42) 100 cases of human tapeworm infections were treated. He concludes, "In . . . any town where large portions of the inhabitants are infested with tapeworm . . . sewage and sewage sludge must present a real danger."

10. Under Annotations (10) it is noted that Leptospirosis is essentially an occupational disease. Human infection is acquired through the alimentary tract or by contact with contaminated water or other material. It has occurred "during the last few years among . . . sewer workers in London and Glasgow . . ., and workers in the beet fields in Ireland, who are probably infected through abrasions of the hands in the same way as are the sugar cane cutters in Queensland."

11. Mills et al. (11) conducted laboratory investigations to determine whether the bacteria penetrated the surface of fruits and vegetables. They found that although bacteria do not penetrate the uninjured surface, they may gain entrance through damaged or decayed surfaces and remain viable for from 7 to 42 days. They also demonstrated that bacteria may persist on the surface of fruits or vegetables kept moist for 15 or more days.

12. Kligler (12) investigated the survival and dispersion of typhoid and dysentery bacilli in soil. These bacteria were recoverable from artificially inoculated moist soil (pH 6.6-7.4) for 70 or more days, but were not recoverable in dry soil on the 20th day. They penetrated to a depth of 2, but not 3, feet in 40 days in relatively porous soil under a 1 to 2 inch head of water.

13. Melick (13) in three outdoor experiments, extending from May to September, isolated typhoid bacteria from garden soil 41, 34 and 35 days after inoculation with typhoid bearing excreta. Under hot house conditions old strains of typhoid bacteria survived for 74 days in garden soil enriched with sterile sewage; fresh strains survived only 49 days. In these experiments typhoid bacteria were found on radishes grown in infected soil 37, 28 and 35 days, and on lettuce after 21 days, after inoculation of the soil. The organism became attached to the surface and was not ordinarily removable by washing.

14. Creel (14) investigated the viability of typhoid bacilli on garden truck. He reports 3 experiments in which radishes and lettuce were raised on soil sprinkled with a fecal emulsion mixed with 24-hour old culture of typhoid bacilli 2 or 3 days after the planting.

He states, "that plants cultivated in contaminated soil will take up on the leaves and stems, as they grow through the soils, organisms existing therein."

"The Bacillus typhosus (typhoid bacillus) was recoverable from the tips of leaves that were, to the named eye, free from soil" and that when these vegetables were grown under natural conditions (except for the artificial inoculation of the soil) the infectious material could be isolated from the leaves up to 31 days.

"Rainfall will not free the vegetables from the infected material."

15. According to Melick (13) "Morse (15) attributed 49 typhoid cases among inmates of an insane asylum to the eating of celery." Typhoid cases had occurred in the institution a few months previously, the celery bed received the institution's sewage, and the epidemic occurred soon after the first use of the celery.

16. According to Melick (13) "Picley (16) records 2 cases of typhoid from eating uncooked rhubarb, which was grown on soil known to be fertilized with typhoid bearing excreta."

17. Veatch (17a) in discussing the Denver, Colorado, sewage disposal problem notes that on certain days the Denver sewage accounts for 97 percent of the flow of the South Platte River, which is used for irrigation immediately downstream. He refers to the construction at Denver in 1937 of a sewage treatment plant which included "fine grained rapid sand filters to secure a high rate of removal of suspended solids and incidentally the removal of . . . the encysted type of amoeba (Endamoeba histolytica) which is strongly suspected of being responsible, through the medium of sewage irrigated vegetables, for a considerable amount of sickness in this area." (Abstractor's note: The magnetite filters referred to did not operate satisfactorily and their use was discontinued).

18. Tanner (18) points out that missed cases and carriers may always be present and that sewage should always be regarded as containing infectious organisms. The work of several investigators is cited and Tanner concludes that (18a) "Sufficient data . . . have been recorded to justify the conclusion that polluted soil may infect vegetables grown on it." He adds (18b) that "good epidemiological evidence seems to exist in the literature to the effect that fresh vegetables may and have caused communicable diseases and that the sanitary condition of the soil from which they are harvested is important." - and finally (18c) that "This review of the literature quite clearly indicates that fresh vegetables which are raised on polluted soil may transmit pathogenic bacteria."

19. Rider (19) in commenting on irrigation in Arizona notes the insanitary practices of many camps of agricultural workers and the use of the main canals for drinking water, swimming, washing clothes, etc. In spite of such conditions only a few instances were noted where water-borne diseases were attributed to canal water. Several years ago, as the result of a newspaper syndicated article, the state laboratory undertook bacteriological examination of lettuce. Many heads -- from 16 fields in the Salt River Valley and from two in Eloy district -- were cultured but no evidence of typhoid or allied organisms was found. Although the technique used was rather hastily devised, it was felt any general contamination would have been indicated.

20. The Committee on Sewage Disposal, American Public Health Association (20) notes in 1937, that "California, alone, out of 33 states reporting, . . . has adopted regulations under its Public Health Act whereby the disposal of sewage, sewage effluent or sludge for irrigation or fertilizing purposes" requires a permit from the State Board of Health. Briefly these California Regulations require that raw sewage shall not be used for irrigating growing crops, and settled or undisinfected sewage is banned for the irrigation of growing vegetables, garden truck, berries, or low-growing fruit, or for watering vineyards or orchards where windfalls or fruit lie on the ground.

21. The Committee on Utilization of Sewage Sludge as Fertilizer, Federation of Sewage Works Associations, in their report (21) in 1942, notes the California regulations are still in effect. Several other states regulate or advise regarding use of sewage sludge.

22. Rawn (22) notes that as of June, 1934, 39 states and the District of Columbia had replied to a questionnaire on use of sewage for irrigation. Thirty states reported neither sewage nor sewage-polluted waters were used for irrigation within their boundaries. Seventeen of these states reported they would not tolerate such use, and the other 13 found it repugnant.

"In the 9 states which admitted use of sewage for irrigation, the attitude was one of tolerance . . . and rigid regulations of the production of the effluent as well as the nature of the crops for which it was to be used."

23. De Martini (23) mentions the following regulations concerning irrigation with sewage and sewage-laden waters:

(1) Colorado - "Requires written permission of State Board of Health for use of sewage or sewage-polluted waters when Coli-aerogenes group of bacteria exceeds 10 per cc."

(2) California and Oregon - "Prohibit use of raw sewage for irrigating growing crops. Prohibit use of settled or undisinfected sewage effluents on growing vegetables and garden truck. Highly oxidized and disinfected sewage effluents can be used provided they meet drinking water standards in Oregon and in California if not over 10 percent of 10cc. portions are positive for the Coli-aerogenes group. Also no single sample can be positive for over half of the 0.1 cc. portions examined."

References

(1) Davidson: Canadian PHD, 33, 305 (1942).

(2) Chapman, Edward N.: "Sewage Contaminated Irrigation Water - A Major Public Health Program in the West." Am. J. Publ. Health, 25, 930 - 937 (1935).

(3) Lumsden, L. L., and Anderson, John F.: "Report No. 4 on the Origin and Prevalence of Typhoid Fever in the District of Columbia" (1909 - 1910), Hygienic Lab. Bull. No. 78 (1911). (3a) p. 159; (3b) p. 194; (3c) p. 196.

(4) Bundesen, Herman N.: "The Control of Foods Eaten Raw." J. Am. Med. Asso., 85, 1285-1288 (1925).

(5) ______________: Annotations "Enteric Fever Spread by Watercress." Lancet, 1903 Vol. 2, 1671.

(6) ______________: "Typhoid Fever in Paris." J. Am. Med. Asso., 80, 1628 (1923).

(7) ______________: "Salvage of Sewage, Final Report of the Joint Committee of the Sanitary Engineering Division and the Irrigation Division on the Salvage of Sewage." Trans. Am. Soc. Civil Engr. 107, 1652-1687. (1942) (7a) p. 1657; (7b) p. 1659.

(8) Roberts, F. C., Jr.: "Experience with Sewage Farming in the Southwest United States." Am. J. Pub. Health 25, 122-125 (1935).

(9) Wilson, H.: "Some Risks of the Transmission of Disease During the Treatment, Disposal and Utilization of Sewage, Sewage Effluent and Sewage Sludge." Jour. and Proc. (Brit.) Inst. of Sew. Purif. (1944). Abstract in Sew. Works Jour. 17, 650-652.

(10) ______________: Annotations "Leptospirosis." Lancet (Brit.), 1939 Vol. 2, 569-570.

(11) Mills, Ralph G., Bartlett, Clifford L., and Kessel, John F.: "The Penetration of Fruits and Vegetables by Bacteria and Particulate Matter, and the Resistance of Bacteria. Protozoan Cysts and Helminth Ova to Common Disinfection Methods." Am. J. Hyg. 5, 559-79 (1925).

(12) Kligler, I. J.: "Investigation on Soil Pollution and the Relations of Various Types of Privies to the Spread of Intestinal Infections." Monograph No. 15 The Rockefeller Institute for Medical Research, (Oct. 10, 1921).

(13) Melick, C. O.: "The Possible Spread of Typhoid Infection Through Vegetables." Jour. of Inf. Diseases, 21. 28-38 (1917).

(14) Creel, R. H.: "Vegetables as a Possible Factor in the Dissemination of Typhoid Fever." Pub. Health Reports, 27, 187-193 (February 9, 1912).

(15) Morse: Report of Board of Health, Massachusetts p. 761 (1899). (According to Melick).

(16) Pixley: N. Y. Med. Jour. p. 98 (1913). (According to Melick).

(17) Veatch, N. T., Jr.: "The Use of Sewage Effluents in Agriculture." Modern Sewage Disposal, Fed. of Sewage Works Asso., 180-190 (1938) (17a) p. 186.

(18) Tanner, Fred W.: "Public Health Significance of Sewage Sludge When Used as a Fertilizer." Sew. Works Jour., 7, 611-617 (July, 1935) (18a) p. 615, (18b) p. 612 (18c) p. 613.

(19) Rider, Jane H.: "Sanitary Features in Irrigation." Am. Jour. Pub. Health, 20, 1187-1191 (Nov. 1930).

(20) Committee on Sewage Disposal, Am. Pub. Health Asso.: "The Utilization of Sewage Sludge as a Fertilizer." Sew. Works Jour. 9, 861 (1937).

(21) Sub-Committee on Utilization of Sewage Sludges as Fertilizer. Fed. Sew. Works Asso.: "Utilization of Sewage Sludge as a Fertilizer." Fed. Sew. Works Asso., Manual of Practice No. 2, 85 (1946).

(22) Rawn, A. M.: "Salvage of Sewage Studied." Civil Engr. 471 (Sept., 1934).

(23) DeMartini, F. E.: "Water Quality Standards." Notes and Lectures from Sanitary Engineering Training Course, U. S. Public Health Service, Cincinnati, Ohio, p. 185 (March 15 - April 2, 1948).

APPENDIX D

NITRITES AND NITRATES IN WATER SUPPLIES

GENERAL

Decomposition of organic material resulting from bacterial action forms a number of nitrogen compounds, including mineral nitrate salts. The amount of nitrates found in water serves to indicate the progress toward complete oxidation and stability. In areas where nitrate fertilizer is used nitrate may be washed from the soil, and may appear in both shallow and deep ground waters over a considerable area. Wells near fields of alfalfa or other legumes might receive some of the nitrate which these plants add to the soil (7). Recent investigations have focused attention to findings of nitrates in water supplies because of its recent relationship to infant cyanosis.

Turneaure and Russell state: (1) "Because of the occurrence of deposits of nitrate nitrogen in certain areas of the earth's surface, and because of constant presence in most soils to the extent of 5 to 100 parts per million, the mere presence of small amounts (up to probably 5 parts per million) of nitrogen in well and spring water should not be considered sufficient reason for condemnation of the supply, especially if bacteriological evidence is negative. Since nitrate nitrogen occurs in oxidized sewage effluents in amounts as high as 20 parts per million, and higher in soil leachings from around manure piles and privies, it seems reasonable to consider the presence of nitrate nitrogen above 5 parts per million as indicative of dangerous pollution."

Until recently mineral nitrates have been considered harmless and in the same light as the chloride content of water supplies.

Infant Cyanosis

Infant cyanosis was generally accepted as being due to congenital heart defect. Thus nitrate poisoning, the cause of infant cyanosis, was overlooked because symptoms resembled those of babies afflicted with heart defects. The medical explanation of nitrate poisoning dates back to 1928. At that time it was learned that nitrate reduced to nitrite in the body would combine with the red oxygen carrying hemoglobin or blood pigment to form methemoglobin, a brownish colored compound. The skin would then attain a grayish-blue color.

Observations of an Iowa physician in 1945 (2) with respect to the relationship between cyanosis of infants and nitrates in water led to the suggestion of upper nitrate limit of 10 parts per million in Iowa water supplies. The linking of nitrates and infant cyanosis in infants aged six months or under, and the nonsusceptibility of older children and adults led to additional investigations. Numerous cases in Iowa have opened the field to a more definite recognition of the cause and effect of infant cyanosis.

In Minnesota (6), data compiled by the State Department of Health bear out the fact that waters containing 10 to 20 parts per million of nitrate affected infants two months old and younger by methemoglobinemia. Walton (8) reports that in the period 1947 to 1949, 139 cases of methemoglobinemia occurred in Minnesota with 14 deaths, and during the same period 9 cases and 1 death occurred in North Dakota from the same cause.

Thirteen cases in Nebraska (4) have been accepted as being due to the ingestion of nitrate in formulae concocted using well water. There is a possibility that a more complete epidemiology would add to this total. It is important to note that data in the examination of the 13 cases included analysis of the water. The range of nitrate nitrogen was 36-200 parts per million. South Dakota has reported several cases of methemoglobinemia (8).

In Missouri in 1948 experiments conducted upon two groups of infants brought out that infants with gastric acidities of pH 4 or above and nitrate-reducing bacteria in the upper intestinal tract developed infant cyanosis upon drinking water containing nitrates. Infants possessing a gastric acidity with pH less than 4 did not develop cyanosis despite the fact that they were fed water of high nitrate content. Nitrates when introduced into the colon, which always contains nitrate-reducing bacteria, irrespective of the gastric pH, caused cyanosis. This experiment showed nitrate reducing bacteria do not find favorable condition in an acid environment. Nitrite was not formed and therefore could not combine with hemoglobin to form methemoglobin with resulting skin discoloration.

Occurrence of Nitrates

Fair (3) mentions that nitrates in surface waters come largely from soil where there is a constant mineralization of nitrogenous organic matter. The nitrate content of water which has undergone heavy pollution with soil washings or human wastes far upstream may be several parts per million.

Large amounts of nitrates varying from one to several parts per million may be found in shallow ground waters which receive local pollution. Another cause for the high nitrate content may be due to oxidation of soil nitrogen. The former is an element of considerable sanitary importance in addition to its position in the infant cyanosis picture.

Other pollution factors remain to be established in a determination of high nitrate contents of deep well waters in locations where the source of contamination has not been determined.

The North Dakota State Department of Health (9) has an established program for testing samples submitted from all rural water supplies for nitrates. Although no correlation is apparent between the nitrate content of a well water and its bacteriological content, the Health Department urges well owners to construct their wells in accordance with approved methods to prevent entrance of barnyard wastes. A check for nitrate content before the water is used to supplement milk formula fed to infants is also suggested.

Public Health Significance

The recognition of the public health significance of methemoglobinemia has led to an increasing number of investigations. The North Dakota State Health Department laboratories have maintained a constant record of the nitrate content of water samples submitted for nitrate and bacteriological examination for the past five years (10). A statistical analysis of the 950 samples reveals that approximately 43 percent of the very shallow wells (10 to 20 feet) have an excessive nitrate content. The number of wells with high nitrate contents decreases uniformly with an increase in depth. Only eight percent of the wells of a depth of 105 to 125 feet contained nitrates in excess of 10 parts per million. From this information it appears that nitrates are introduced into the underground waters through percolation. The results are actually an indication of the depth to which ground water recharge from local sources is effected. It is also revealed that maximum amounts of nitrate appear in the water during periods of heavy runoff (spring and fall) and are at a minimum during periods of extreme cold or drought.

An average of 25 percent of all private water supplies in North Dakota contain 10 parts per million or more of nitrates as nitrogen.

SUMMARY

Nitrates in waters have been found to cause methemoglobinemia in infants aged six months and less. Older children and adults are not affected.

Epidemiology of infant cyanosis indicates a greater incidence of nitrate poisoning than that indicated by reported cases.

Satisfactory reports of the usual water examinations do not indicate such waters to be free of high and possible harmful high nitrate concentrations. A greater percentage of the wells with high nitrates will show bacterial contamination than wells with low nitrate values. Boiling waters containing low nitrate content will result in a higher nitrate concentration, thus possibly rendering the water nocuous.

A maximum figure of 10 parts per million has been suggested as the upper limits of nitrates in well waters to be used in infant feeding.

BIBLIOGRAPHY

(1) Turneaure and Russell: "Public Water Supplies" - John Wiley & Sons.

(2) Comly, H. H. - "Cyanosis in Infants Caused by Nitrates in Well Waters." Journal A.M.A. 129-112, Sept. 1945.

(3) Milton J. Rosenau - "Preventive Medicine and Hygiene," Appleton-Century.

(4) Jeanette M. Debus - "Nitrates and Nitrites in Nebraska Water Supplies," University of Nebraska Publications, Second Annual Waterworks Conference.

(5) Dugan, F. C. - "The Effects of Nitrites in Rural Water Supplies on Infant Health." Bulletin of Department of Health, Kentucky. Vol. 21, No. 3, Oct. 1948.

(6) H. M. Bosch, et al. "Methemoglobinemia and Minnesota Well Supplies."

(7) John C. Frye, and A. R. Leonard. "Geology and Ground Water Resources of Norton County and Northwestern Phillips County, Kansas."

(8) Graham Walton - "Survey of Literature Relating to Infant Methemoglobinemia due to Nitrate Contaminated Water." Environmental Health Center, Cincinnati, Feb. 1951.

(9) Willis Van Heuvelen - "What About Nitrates in North Dakota Drinking Water?" "North Dakota Official Bulletin, Sept. 1948."

(10) Arthur E. Williamson and Norman L. Peterson - "Nitrates in North Dakota Well Waters." North Dakota Official Bulletin, Sept. 1951.

APPENDIX E

LIMNOLOGICAL FEATURES OF THE RED RIVER OF THE NORTH

The Red River and those portions of its major tributaries that lie within the Lake Agassiz plain are quite similar in appearance. Bottoms are of mud and muck with occasional sand bars; banks are muddy, fairly high, and steep; margins are usually tree covered; and channels frequently contain logs and fallen trees. Mucky bottoms are built up by the black soil of the valley, marsh vegetation in drainage ditches, aquatic vegetation in the tributary streams, sewage discharges, and trees bordering the streams. The Red River bottom at Grand Forks is affected by discharge of lime sludge and filter and settling basin washings from the water treatment plant. A grayish sludgy deposit exists around the outfall and on downstream below the mouth of the Red Lake River (figure 1). It is probable that lime sludge filter backwash and settling basin sludge also influence the river bottom at Fargo. Drainage ditches support considerable vegetation, but contain little or no flow during the growing season.

Reaches of the Red and some tributaries, the Red Lake, Pembina, North Dakota Wild Rice, Buffalo, and Minnesota Wild Rice Rivers that lie in the Lake Agassiz plain, are noticeably turbid during summer months. The Sheyenne and Two Rivers have a muddy appearance due to color of their bottoms, but Goose, Park, and Forest Rivers are usually quite clear. In the plain, only the Park, Forest, Goose, and other smaller tributaries support aquatic plants, but some of the larger tributaries have extensive weed growths nearer their headwaters.

Over 50 percent of the Red Lake River drainage basin consists of water area and undeveloped peat and swamp lands. Most extensive swampy areas are in the northwestern portion. Attempts made during the period 1910-1916 to reclaim large areas of swampy land by construction of ditches and other drainage structures were unsuccessful as considerable portions of such lands proved unsuitable for profitable agriculture. Most of the Red Lake River watershed lies in old Lake Agassiz. The river begins as an outlet from Lower Red Lake, and for its first 37 miles is practically indistinguishable from surrounding swamplands. Below High Landing, Minn., height of banks increases and a valley develops. Below Thief River Falls the Red Lake River has a well defined channel in a deep valley eroded through the glacial lake plain.

Clearwater River, tributary to the Red Lake, rises near Ebro, Minn., and, after starting toward the east, turns north and west to join the latter at Red Lake Falls. The middle section of this stream (Butcher Knife to Plummer) lies in a flat swampy area, where its channel is not well defined, and where its flood waters often mingle with those of the Red Lake River over the inconspicuous ridge that separates the two drainage basins. Below Plummer it develops a deep channel and valley with steep slope.

Thief River originates at Thief Lake, also a remnant of Lake Agassiz, and flows through the glacial lake plain its entire length. Tops of its banks are at the level of the plain in general. Mud River enters from Mud Lake. Both Mud and Thief Lakes have been developed as waterfowl refuges, with dams constructed at their outlets to furnish refuge pools. The Thief River channel has been straightened and enlarged from a point six miles above its mouth 25 miles upstream.

Upper and Lower Red Lakes have a combined area of 440 square miles and are connected by a mile wide straight known as "The Narrows." The lakes are shallow with very flat shores and have no natural harbors except in the mouths of some entering streams. Most inflow is carried by the Tamarack River into the eastern end of Upper Red Lake, and by the Cormorant and Battle Rivers into the east end of Lower Red Lake. Flat swampy areas extend 25 miles back from the lakes to the north. In 1931 the Indian Service constructed a control structure, a combination dam and bridge, across the outlet of Lower Red Lake for lake regulation and flood control.

Flows in Clearwater and Red Lake Rivers are restricted by plant growths, mostly slough grass and reeds, thereby reducing channel efficiency in the Red Lake above High Landing, and in the Clearwater above Plummer. Weed clogging of channels is considered an important cause of summer floods. Swampy areas contiguous to lakes and rivers in this area support considerable numbers of waterfowl and fur bearing animals.

The Sheyenne and its main tributary, the Maple River, are very similar. The Sheyenne rises in marshy uplands of central North Dakota, where it has a slope of about 1.7 feet per mile. In its lower regions slope decreases to about 1.3 feet per mile. The Pembina River, heading in the Turtle Mountains and drift prairies of southern Manitoba, has an average slope, exclusive of the Turtle Mountain portion, of 3.8 feet per mile. Mineral content of streams entering the Red River from the west is noticeably higher than that of its eastern tributaries.

The Red River receives effluents from secondary treatment plants at Fargo and Moorhead from a primary treatment plant at Grand Forks, and receives untreated wastes from East Grand Forks, Oslo, Drayton, Halstad, and other small communities. Sewage and sugar beet wastes from East Grand Forks reach the river just above Riverside Park Dam. Untreated wastes from a large packing plant and a flour mill, in addition to the Grand Forks sewage treatment plant effluent, are discharged to the river just below this dam. The outfall from the sewage treatment plant at Fargo is located one-half mile upstream from Station 11, while effluent from the Moorhead plant enters the river six miles above (figure 1).

The Red River furnishes cooling and boiler water for two power plants at Grand Forks. Return flows from these installations reach the river just above a bridge on U. S. Highway No. 2, and just above the Riverside Park dam. Oily wastes formerly produced by a gas plant were evidently discharged to the ground through a faulty pipe system and now reach the river from ground storage near the discharge from the upper power plant. This oil produces a film that covers about one-half the river surface.

The Red Lake River is polluted by sewage from Crookston, Thief River Falls, Red Lake Falls, and other upstream communities, but is free of such discharges in the region of its mouth. Some wastes from Pembina reach the Pembina River just above its mouth. The Sheyenne River receives, 20 miles above its mouth, packing house wastes that are treated to remove 95 percent of the B.O.D.

Smaller tributaries are contaminated in stretches remote from their mouths. Two Rivers receives Hallock and Lancaster sewage; Park River, Grafton and Park River sewage; Goose River, Hillsboro and Mayville sewage; Snake River, Warren sewage; Minnesota Wild Rice River, sewage from Twin Valley and Mahnomen; and Buffalo River, sewage from Hawley and Barnesville. Discharge from the majority of these streams amounts to very little during critical low flow periods, and at those times pollution along their courses does not reach the Red River.

Chemical Features

The basic water chemistry of the Red River is largely the result of dilution of moderately mineralized waters from the North Dakota tributaries with softer waters coming from swamp and marsh areas along the upper reaches of the major Minnesota tributaries. In August 1951, total alkalinity of the Red River was reduced from 171 to 143 ppm. by entrance and mixing of a slightly greater amount of Red Lake River water with total alkalinity of 131 ppm. Discharge of the Sheyenne River amounted to about 50 percent of that of the Red River, and entrance of this water with total alkalinity of 211 ppm. raised that of the Red River from 160 to 171 ppm. Total alkalinity was more markedly affected by photosynthesis in smaller North Dakota tributaries where its range was from 64 to 156 ppm. Discharges from these streams were inadequate to provide a measureable influence upon the Red River. Two Rivers, in Minnesota, with a total alkalinity of 212 ppm. did not alter that of the Red River as its volume of discharge was only about 1/100 that of the Red.

Oxygen

During open water periods natural oxygen-reducing processes appear to keep oxygen level in the range of 80 to 90 percent saturation in those parts of the Red River not markedly affected by photosynthesis or municipal sewage and industrial waste discharges. Photosynthesis affects the Red River appreciably only at very low flow, but sewage and waste discharges, particularly below Fargo-Moorhead and Greater Grand Forks, influences oxygen content at all stream levels. Oxygen depression occasioned by these wastes varies, but available records show a measurable decline at or just below each of these two urban areas. At Fargo-Moorhead and above, aeration of water is facilitated by dams. No dams are present in the stretch between Fargo and Grand Forks; the Riverside Park dam is located just below Grand Forks; and the Red Lake River is dammed just above its confluence with the Red River. Turbulence created by flow over dams brings oxygen levels nearer the saturation point. Reaeration afforded by Red Lake and Red River dams at Grand Forks counteracts, for a short distance below, the effects of oxygen depleting substances that enter the river in and above this reach. During open water periods in which recent sampling programs have been carried out, the discharge of the Red Lake River amounted to slightly more than that of the Red River. A short distance below the lower dam, oxygen again declined and usually did not regain the saturation level evident above Fargo-Moorhead and Grand Forks until the stream reached Drayton; although, upon occasion, oxygen depletion was progressive to the International Boundary. During a period of extremely low flow in 1939, photosynthesis in the stream a short distance below Fargo-Moorhead produced a masking effect upon oxygen depleting substances discharged at Fargo and Moorhead, but here again the sharp rise (in this instance to above the saturation point) was followed by decline to below the level exhibited above Fargo-Moorhead.

During periods of ice cover, Red River oxygen content usually evidenced progressive decline below Fargo and often approached the zero point just above Grand Forks. Dams in the Red Lake and Red Rivers at Greater Grand Forks brought about a sharp increase in dissolved oxygen, which persisted for varying distances downstream. However, when decline again set in, it was progressive all the way to the Canadian Border. It seems that natural contributions of oxidizable material severely reduce oxygen during conditions of ice cover, and this occurrence makes release of sewage and industrial wastes all the more critical. Stretches of open water and aeration induced by dams in the region of Grand Forks and above Fargo are apparently the only factors that prevent absolute winter oxygen depletion over much of the river.

Oxygen concentrations from supersaturation to slightly less than 60 percent saturation occurred during open water periods in various tributaries. Although discharge from the Red Lake River was fairly high in oxygen due to the overflow dam just above its mouth, oxygen concentration above the dam was the same as that of the Red River upstream as determined by sampling in August 1951 (63 percent saturation). The Sheyenne and North Dakota Wild Rice Rivers both had oxygen concentrations at 60 percent saturation during August 1951, but the Goose, Park, Forest, and Two Rivers were supersaturated at the same time. It appears likely that discharge from the Sheyenne may affect the oxygen concentration in the Red River, and that no measurable influences result from inflow of the supersaturated tributaries. Under conditions of fairly high flow, as existed in the Red River during sampling periods in 1950 and 1951, photosynthesis noticeably affects oxygen concentrations only in these smaller streams, since both Red and Red Lake Rivers are too turbid to promote growth of algae and other aquatic plants except at their extreme margins. During periods of extremely low water levels, growth of photosynthetic organisms on the Red River bottom is possible, and activities of such benthic forms and plankton algae bring about supersaturated oxygen levels.

Biochemical Oxygen Demand

The Red River appears to have a B.O.D. from natural sources that amounts to around 3 ppm. in summer and 2.5 ppm. in winter. Sewage and industrial waste discharges augment the natural supply of oxidizable organic materials and induce B.O.D. levels that average as high as 8.5 ppm. below Fargo-Moorhead and more than 6 ppm. in the river at Greater

Grand Forks. Some B.O.D. determinations at the last two or three stations above the International Boundary have been exceptionally low (averaging only 0.1 or 0.2 ppm. in 1950) and it is possible that these low values may result from the presence of interfering cations of copper and zinc and not from low quantities of organic materials. Analyses of samples collected in August 1951[1] disclosed the presence of both copper and zinc (0.13 ppm. Zn and 0.5 Cu) in one sample of water from the Red Lake River at East Grand Forks. The Red River at Oslo showed approximately one-half these amounts, indicating that the Red Lake River is the principal if not the only source of these cations. Quantities present in the Red River at Station 4 (Oslo) are apparently sufficient to interfere with bacterial action.

Other Chemical Features

Water of the Red River system is alkaline in reaction during both open water and ice cover seasons. During the latter season decomposition reduces pH below the level of 8.0 and gives some free CO_2 in solution. During summer, spring, and fall, pH is 8.0 or above, and its winter decline is down to the region of 7.5. Photosynthesis raises pH to 9.0 and above in the smaller clear tributaries and in the Red River itself during extremely low stages. Nitrate analyses of the Red River and tributaries have not been performed routinely in any surveys for which records are available. One record for August 1951 shows 0.8 ppm. in the Red Lake River at East Grand Forks and 1.6 ppm. in the Red River at Oslo, Minn. Nitrite analyses were conducted on a routine basis during the period 1938 to 1940 when largest amounts (max. 0.97 ppm. NO_2 N) were present just below Fargo. It would appear that nitrite at this location arises from oxidation of ammonia contributed in sewage and industrial wastes. It would also appear from review of these data, that nitrite is added in a similar manner to the river at Grand Forks, although in lesser quantities. Nitrite also occurred in some of the smaller tributary streams, where, in some instances, its presence appeared due to decomposition of blue-green algae. This condition characterized Two Rivers during August 1951 when nitrite concentration was 0.06 ppm. NO_2 N. In such instances nitrite production must be considered natural.

Biological Features

During periods of rather high flow, such as existed in August 1950 and 1951, the Red River was sufficiently turbid to interfere with light penetration; and plant growth, at least benthic forms, was not well developed. Benthic algae were not evident at most of the stations examined in August 1951. In the few localities that contained them in observable quantities, they occurred only along the margins and on branches of waterlogged trees. At Station 11 (see appendix F for station description), *Cladophora* was present on those branches of waterlogged trees that came to the surface of the river, and a narrow belt of diatoms occurred at the extreme margins of the stream. Similar growths, although less developed, occurred at Station 10, and at two points between Stations 10 and 11. Some of the tributary streams

---

[1] The U. S. Geological Survey's cooperation in conducting these analyses is gratefully acknowledged.

(Park, Forest, and Goose Rivers) contained dense growths of aquatic flowering plants (principally _Potamogeton pectinatus_) on their bottoms, and some other clear streams (Two Rivers and Sheyenne River) possessed observable quantities of both plankton and benthic algae. Two Rivers had a bloom of _Anabaena_ that influenced both oxygen and nitrite content of the water. The Red Lake and Pembina Rivers were very similar in appearance to the Red River, and no benthic plants were noted in either. Plankton analyses made during September 1950 and February 1951 by the Minnesota Department of Health are available and will be considered later.

Bottom Organisms

Organisms (animals) that dwell in bottom deposits of still and flowing bodies of water adapt themselves to one or more of the various situations that may be encountered in any one lake or stream. Stream bottoms under natural conditions vary considerably, and offer several types of environment. Two major assemblages of bottom organisms, one in pools and one in rapids, occur in headwater streams.

Character of stream bed and the chemical and physical conditions of the water determine the preference of an organism for either a riffle or a pool. Due to greater velocity of flow, bottoms of riffles are usually composed of coarser and heavier materials than those of pools, although small pockets of finer materials are found on riffle bottoms in slack current spots on the downstream sides of large stones and other obstructions. Pool bottoms usually contain larger deposits of finer and lighter materials and much more organic material than riffle bottoms, although this material may be present in rather concentrated amounts in small isolated areas on many riffles. Organisms that prefer moderate to heavy concentrations of organic matter are more apt to occur in pools, although their presence on riffles is not unusual. Animals that have adapted themselves to the swifter water and bottom conditions of riffles, on the other hand, are seldom found in pools.

In a stream not divided into riffles and pools but consisting of a fairly uniform, slow flowing current throughout, both riffle and pool bottom organisms usually occur, although their areas of abundance are not as distinctly demarcated as in a typical headwater stream. Under natural conditions it is quite normal for a varied assemblage of bottom organisms to occur in any one general area of a slow uniform stream. However, detailed studies will usually show that the normal riffle organisms are selective in picking out areas in which organic deposits are not very great, and that usual pool organisms may occur in most concentrations of organic materials. The predominance of riffle or pool organisms in a slow flowing stream is normally influenced by the relative abundance of organic detritus. Since in a majority of instances slow flowing currents usually permit rather heavy deposit of organic particles, those organisms that usually dwell in headwater stream pools are more numerous than their riffle inhabiting counterparts in such a stream as the Red River of the North. Discharge of organic wastes into a stream of this sort augments the quantity of naturally deposited organic bottom materials, and often brings about conditions that are tolerated only by those organisms that normally prefer a high degree of decomposing organic material.

These facts have resulted in a classification of bottom organisms with regard to their tolerance of organic pollution. This system recognizes three major groups, clean water, facultative, and pollutional. In many respects this classification is one of convenience and organisms do not always fit definitely into any group.

In general, the clean water species are those riffle inhabitants of headwater streams that have become adapted to fairly clean bottoms and high oxygen content of water, and are therefore the first to disappear in the face of pollutional discharges. Facultative species include those pool inhabitants that normally seek areas containing appreciable quantities of organic matter, and hence may be able to survive varying degrees of sewage and waste contamination. Pollutional species are the most tolerant of all with regard to bottom contamination and are able to survive when all others, including facultative organisms, are killed off. Hence, the greater the degree of organic pollution the fewer the species of bottom organisms represented, and vice versa. Some pollutants are toxic to all benthic organisms and may eradicate completely this segment of a stream's biota.

The life cycles of various bottom organisms must be taken into consideration before valid interpretations of analyses may be made. A large number of species are nymphs and larvae of various insects that periodically transform into winged adults that supply the eggs for the next generation of immature stages. The length of time required for insects to mature from the egg to the adult stage varies from a few days or weeks to as much as two years. A great number of bottom dwelling forms have long life cycles and analyses of these species often permit insight into long range stream condition. Due to the fact that transformations from larval and nymphal stages into adults deplete the supply of immatures in a stream for more or less extended periods of time, seasonal cyclic phenomena must not be ignored in interpretation of bottom sample data. Normally, numbers of insects in the bottom fauna are greater during winter than at other seasons.

Red River bottom samples taken during September 1950 and February 1951 by the Minnesota State Department of Health consisted of two Eckman dredge hauls at each of the stations listed in tables E-1 and E-2. Differences that may be noted both in species present and total numbers of organisms may be attributed partly to the very limited area sampled upon each occasion and partly to seasonal variation. The bottom samples are sufficiently representative to indicate those areas most affected by municipal wastes and give a general picture of the effects of pollution along the entire United States portion of the river.

The bottom materials of the Red River, normally mud and muck, are made muckier by waste solids discharged from towns and industries. The benthic fauna showed a definite response to accumulations of these materials by its relative abundance and species composition at the various stations.

Figure E-1 shows total numbers of organisms (per sq. ft). and gives numbers of species and percentages of pollutional forms at each

Table E-1. Red River of the North - September 26 and 27, 1950 - Biological data - Bottom fauna based on two 6 x 6 Ekman dredge samples per station organisms in numbers per sq. yd.*

Station No. Date Sample No.	Sta. 12 9-26-50 4438	Sta. 11 9-26-50 4437	Sta. 10 9-26-50 4436	Sta. 9 9-26-50 4435	Sta. 8 9-26-50 4434	Sta. 7 9-26-50 4433	Sta. M 9-26-50 4432	Sta. 6 9-26-50 4431	Sta. 4 9-26-50 4430	Sta. 3 9-27-50 4429	Sta. 2 9-27-50 4428	Sta. 1 9-27-50 4427
ANNELIDA												
Hirudinea												
Glossiphonia stagnalis			18									
Oligochaeta												
Limnodrilus sp.	72	882	126	522		198	90	1,116	90	450	90	126
Tubifex sp.	72	108	36	36		162		738	36	18	18	
ARTHROPODA												
Insecta												
Coleoptera												
Dytiscidae (adult)						18						
Diptera												
Ceratopogonidae					36					18		18
Chaoborus punctipennis											18	
Chironomus decorus		18					18				18	
Chironomus digitatus		18	414		54							
Chironomus lobiferus	18											
Chironomus militaris	18	72										
Chironomus senilis	18											
Chironomus tentans-plumosus	468											
Chironomus sp.	18	180	342		216			18			18	
Palpomyia flavipes	18											
Pentaneura monilis						18						
Procladius culiciformis	18			216		486		162	18			
Procladius spp.				54		18	18				18	
Psychoda alternata		306										
Tanypodinae		18										
Tanypus carneus?									18			
Tanypus sp.												
Ephemeroptera												
Hexagenia spp.						36	126		72	18	216	54
Pentagenia sp.					648							
Hemiptera												
Callicorixa praeusta							54		36		18	54
Neuroptera												
Sialis sp. Lv.						18						
Odonata												
Progomphus									18			
Trichoptera Lv.?							18					
MOLLUSCA												
Lamellibranchia												
Sphaerium sp.				18	18							
TOTALS	720	1,602	936	846	972	954	324	2,034	288	504	414	252

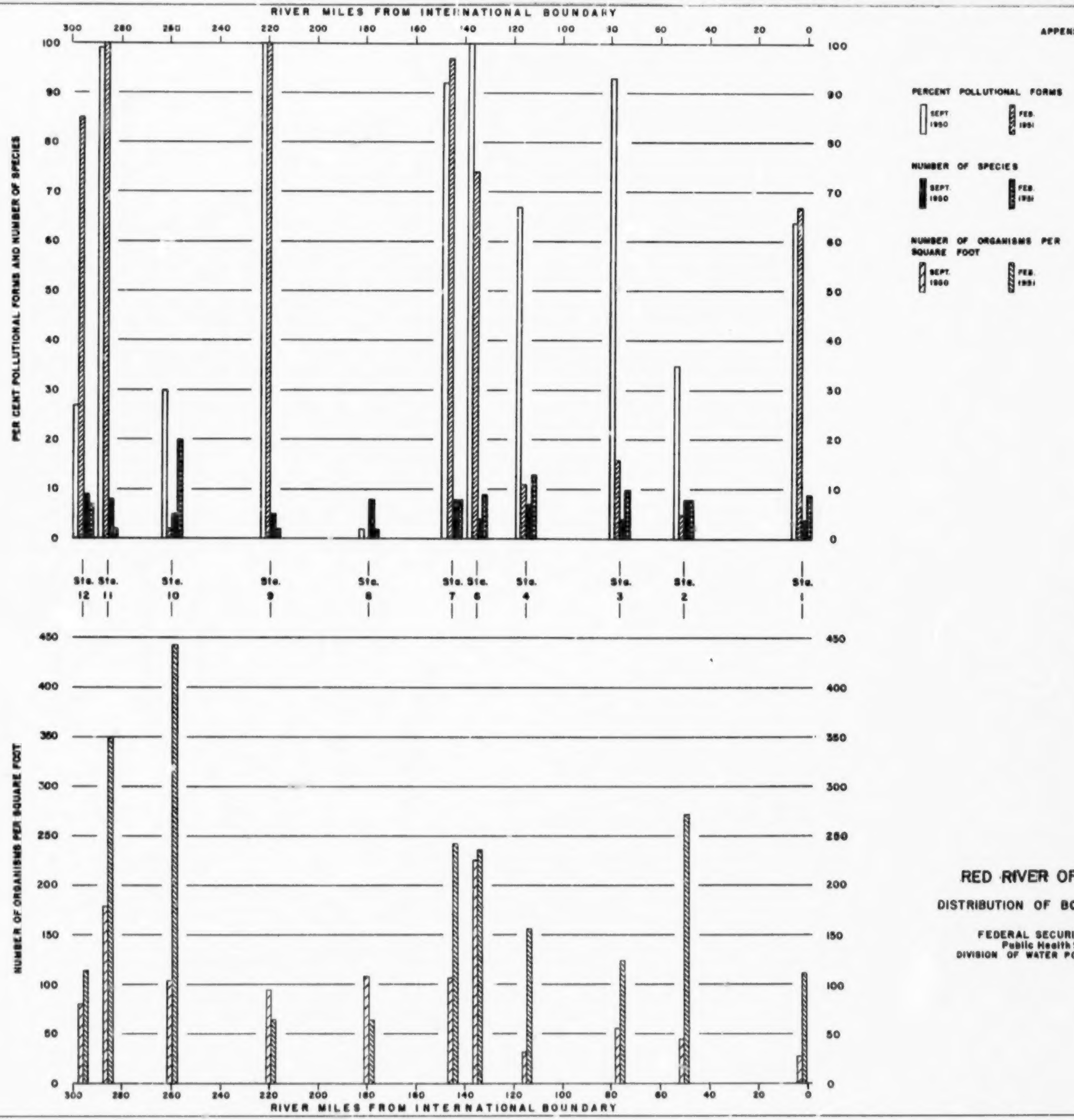
*Data from Minnesota Department of Health

Table E-2. Red River of the North - February 20 and 21, 1951 - Biological data - bottom fauna based on two 6 x 6 Ekman dredge samples per station - organisms in numbers per square yard*

Station No. Date Sample No.	Sta. 12 2-20-51 6330	Sta. 11 2-20-51 6331	Sta. 10 2-20-51 6332	Sta. 9 2-20-51 6333	Sta. 8 2-20-51 6334	Sta. 7 2-20-51 6335	Sta. M 2-20-51 6336	Sta. 6 2-21-51 6337	Sta. 4 2-21-[illegible] 633[illegible]	Sta. 3 2-21-51 6339	Sta. 2 2-21-51 6340	Sta. 1 2-21-51 6341
ANNELIDA												
Hirudinea												
Glossiphonia heteroclita		18	18									
Oligochaeta												
Limnodrilus sp.	36	3,114	36	558		918	162	1,458	90	72	18	360
Tubifex sp.	378					684	54					18
ARTHROPODA												
Arachnida												
Hydracarina	18											
Crustacea												
Hyalella knickerbockeri			18									
Insecta												
Coleoptera										18	72	18
Parnidae (Adults)			18									
Parnidae (Lv.)			90									
Diptera (Lv.)												
Ceratopogonidae			108		18	18	72	54	198			36
Chironomus decorus								18				
Chironomus digitatus	90		162					90	36	18		
Chironomus dimorphus			36									
Chironomus tentans-plumosus	54		72			18						
Chironomus sp. B (Malloch)							36		18			
Chironomus sp.			342		558	18	36		108			36
Chironomus spp.			36			216	108	72	90			378
Orthocladius sp. E.			1,728					36	126	36		
Orthocladius sp.												18
Pentaneura monilis			270									
Pentaneura flavifrons			18									
Procladius culiciformis	414					198	18	18				
Procladius sp.			36									
Spaniotoma nivoriunda			882				18	360	288	72	18	
Syrphidae										36		
Tanytarsus dives			18									
Ephemeroptera (nymphs)									18			
Hexagenia sp.									54	54		
Pentagenia spp.							72					36
Stenonema terminatum							18				18	
Hemiptera												
Corixidae (nymphs)	36											
Arctocorixa sp. (Adults)			18								54	
Callicorixa praeusta (Adults)			18			108	72		342	612	1,926	
Plecoptera (nymphs)												
Isoperla bilineata							36		18	180	216	
Trichoptera (Lv.)												
Hydropsyche sp.			54						18	18	126	108
MOLLUSCA												
Lamellibranchia												
Sphaerium sp.								18				
Stagnicola sp.				18								
TOTALS	1,026	3,132	3,978	576	576	2,178	702	2,124	1,404	1,116	2,448	1,008

*Data from Minnesota Department of Health

APPENDIX "E" FIGURE 1



RED RIVER OF THE NORTH

DISTRIBUTION OF BOTTOM ORGANISMS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

station. In winter, the greatest concentration occurred at Station 10, while in early autumn largest numbers were found just above Riverside Park Dam at Grand Forks (Station 6). Lowest concentrations, in early fall, occurred at Oslo and on downstream, and in winter in the stretch from above Halstad to below Climax (Stations 9 and 8). Percentagewise, pollutional species were most concentrated at Stations 11, 9, 7, 6, 4, and 3 in September 1950. In February 1951 they formed a much smaller portion of the benthic fauna at Stations 3 and 4 but maintained almost their same ratio to facultative and clean water forms at other stations. In most instances number of species was greater during the winter, particularly at those stations having smaller percentages of pollutional species. Concentrations of pollutional species occurred in those regions nearest sources of sewage and other wastes, with four exceptions. The exceptional cases, Stations 2, 3, 4, and 9, seemingly receive quantities of organic bottom sediments during flows associated with ice breakup in the spring. Examination of discharge records shows interferences due to ice jams at or just below each of these stations, and it is reasonable to assume that reduction of current velocity so occasioned permits greater deposition of organic materials at those sites. In the stretch between Stations 11 and 9 increased flow during ice breakup appears to reduce amounts of organic sediments. This scouring action may possibly be augmented by discharge from the Sheyenne River, which enters between Stations 10 and 9, but volume of flow from the Sheyenne normally increases but little the discharge of the Red. Higher river discharges, occurring later in the spring, undoubtedly remove quantities of organic sediments, but they bring about a general reduction along the length of the stream without markedly altering proportionate concentrations established during ice breakup. Breakup flows, while less than those prevailing later in the year, occur at a more strategic time to influence lighter sediments accumulated under ice cover, particularly from sugar beet refineries. Concentrations of organic sediments at points remote from the municipalities may represent quantities contributed by vegetation as well as those arising from waste discharges.

Benthic samples from the Red River aptly illustrate possibilities for wastes contamination in regions remote from their source. Such contaminations have direct effects upon the bottom and, for the most part, probably affect the water only in an indirect fashion. Differences in concentration and composition of bottom fauna at the various stations in Spetember and February may indicate seasonal cyclic effects, but their major cause is as yet indeterminate. Apparent variation is to be expected when circumstances severely restrict size of sample areas.

Species and number of bottom organisms collected at each station during September and February are shown in tables E-1 and E-2. The greater number of species are those favoring organic deposits in their habitats, but clean water forms are not absent from the river. Pollutional species composed 99 to 100 percent of organisms present at Stations 11 and 9 during both seasons, 92 to 97 percent at Station 7, and at other stations exhibited considerable variation. Clean water forms amounted to 70 percent of the total population at Station 10 in September, but comprised only 6 percent in February. At Station 2, no clean water forms were collected in September, yet they formed 90 percent of the organisms taken there in February. Facultative forms showed similar variation at different stations, and were most concentrated at Station 8. It seems that such major differences in clean water and facultative organisms at different times of the year represent the inadequacy of one-half square foot bottom samples to do more than indicate the general effects of pollution.

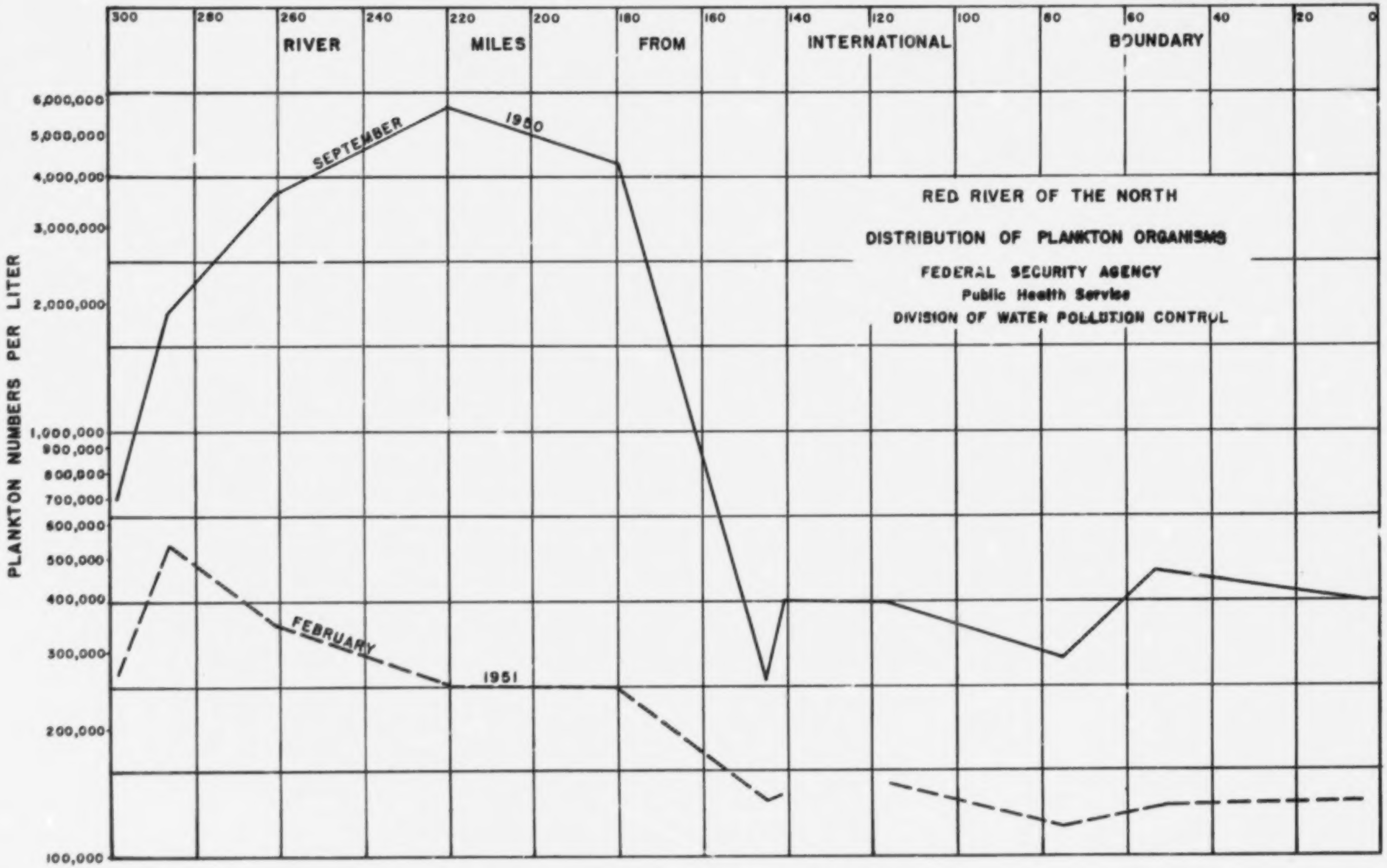
Plankton densities at various stations in September and February are shown in figure E-2, while relative concentration of the various species is given in tables E-3 and E-4.

Plankton organisms, being more subject and more sensitive to physical and chemical changes in the water, are usually considered less indicative of long term stream conditions than the bottom fauna. However, the sensitivity of various plankters to chemical changes upon occasion permits very accurate delimitation of the downstream effects of certain wastes, and it is frequently desirable to make plankton studies in order to ascertain its influences upon water chemistry (B.O.D., dissolved oxygen, pH, alkalinity, etc.). Plankton samples collected during September indicate that oxidation of waste products to inorganic salts which have a definite stimulus upon plankton growth, is usually completed by the time wastes from Fargo-Moorheed reach the vicinity of Station 9. The rapid decrease in plankton below Station 9 indicates quick exhaustion of these compounds. Increased volume of flow and greater turbidity militated against plankton growth below Grand Forks, and the picture was further complicated by the dam at Riverside Park. The peak attained at Station 2 may possibly indicate enrichment coming from the accumulation of organic sediments at that point, but a more likely explanation is delay of complete oxygenation of wastes from the Greater Grand Forks area. Studies of various oxygen determinations that have been made along the Red River indicate that on a majority of occasions oxygen recovery to the saturation point present above sources of pollution occurs in the vicinity of Station 9 and Station 2. The dam just below Grand Forks brings about a sudden increase in oxygen content that is usually immediately followed by a decline. Plankton samples considered here do not represent the river just below this dam.

In February 1951, plankton was markedly influenced by ice cover. Open water occurring above Station 11 permitted considerable development but densities declined below that point.

Qualitative aspects of plankton indicate that bottom algae contributed to it in no small measure in the stretch from Station 11 to Station 9.

APPENDIX "E" FIGURE 2



RED RIVER OF THE NORTH

DISTRIBUTION OF PLANKTON ORGANISMS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

Table X-3. Red River of the North - Biological data - plankton organisms based on one two-liter sample per station organisms in numbers per liter--September 26-27, 1950*

Station No. Date Sample No.	Sta. 12 9-26-50 4438	Sta. 11 9-26-50 4437	Sta. 10 9-26-50 4436	Sta. 9 9-26-50 4435	Sta. 8 9-26-50 4434	Sta. 7 9-26-50 4433	Sta. X 9-26-50 4432	Sta. 6 9-26-50 4431	Sta. 4 9-26-50 4430	Sta. 3 9-27-50 4429	Sta. 2 9-27-50 4428	Sta. 1 9-27-50 4427
BLUE-GREEN ALGAE												
Anabaena sp.		5,400	43,200	16,200		10,800					5,400	
Chroococcus dispersus	27,000	37,800	59,400	189,000	145,800			16,200	54,000	5,400	10,800	
Chroococcus minutus						5,400	5,400				5,400	5,400
Merismopedia punctata					27,000							
Oscillatoria spp.	178,200	793,800	1,168,200	405,900	485,100	37,800	10,800	108,000		5,400	21,600	10,800
Spirulina major	5,400											
GREEN ALGAE												
Actinastrum Hantzschii	10,800	43,200	237,600	1,950,300	2,185,500	16,200		21,600	27,000	5,400	5,400	16,200
Ankistrodesmus falcatus					118,800	5,400						
Botryococcus Braunii								10,800			5,400	
Coelastrum microporum									5,400	5,400		
Crucigenia quadrata	16,200		54,000	76,000	210,600		16,200	5,400	27,000	10,800		10,800
Kirchneriella lunaris									5,400			
Oocystis lacustris	10,800	27,000		10,800								
Pediastrum Boryanum	5,400		5,400				5,400					
Pediastrum duplex		10,800	16,200	27,000	10,800				5,400			
Pediastrum simplex					5,400							
Scenedesmus arcuatus	16,200	10,800			253,800	10,800	5,400		5,400			
Scenedesmus bijuga	5,400	5,400	64,800	264,600	178,200	5,400	16,200	16,200	37,800	10,800	10,800	48,600
Scenedesmus dimorphus	10,800	27,000	16,200	48,600	91,800	16,200	5,400	10,800	10,800		10,800	5,400
Scenedesmus quadricauda		27,000	102,600	113,400	16,200							
Staurastrum cingulum		5,400	10,800	5,400	5,400							
DIATOMS												
Cocconeis pediculus							27,000				10,800	
Cyclotella spp.	302,400	540,000	270,000	194,400	54,000	5,400	5,400	16,200	16,200	10,800	21,600	21,600
Cymbella sp.												5,400
Diatoma sp.							5,400					10,800
Fragilaria crotonensis							5,400					
Gyrosigma attenuata			920,700	1,950,300	277,200					5,400		10,800
Melosira granulata	21,600	37,800	21,600	32,400	10,800	10,800	16,200		5,400	5,400		10,800
Navicula spp.	16,200	91,800	76,000	32,400	27,000	16,200	54,000	81,000	32,400	124,000	64,800	113,400
Stephanodiscus spp.	10,800	27,000										
Surirella sp.												16,200
Synedra spp.	5,400	81,000	16,200	5,400	16,200		86,400	70,200	113,400	64,800	248,400	81,000
PROTOZOA												
Chilodon sp.			5,400	5,400								
Chlamydomonas sp.					5,400							
Euglena spp.	64,800	43,200	124,200	140,400	91,800	16,200				10,800	10,800	5,400
Holophyra sp.	5,400											
HOLOTRICHIDA		21,600	113,400	113,400	48,600	86,400		27,000	43,200	5,400	10,800	16,200
MASTIGOPHORA				5,400								
Pandorina sp.		5,400										
PHYTOMONADINA								5,400		5,400	5,400	10,800
Sphaerophyra magna								5,400				
Trachelomonas sp.	5,400	5,400		10,800					5,400	5,400		
Vorticella spp.		5,400		5,400	10,800			5,400				
TOTALS	712,800	1,851,800	3,325,900	5,602,900	4,219,200	243,000	264,600	399,600	394,200	280,800	448,200	399,600

*Data from Minnesota Department of Health

Table X-4. Red River of the North - Biological data - plankton organisms based on one two-liter sample per station organisms in numbers per liter - February 20 and 21, 1951*

Station No. Date Sample	Sta. 12 2-20-51 6330	Sta. 11 2-20-51 6331	Sta. 10 2-20-51 6332	Sta. 9 2-20-51 6333	Sta. 8 2-20-51 6334	Sta. 7 2-20-51 6335	Sta. X 2-20-51 6336	Sta. 6 2-21-51 6337	Sta. 4 2-21-51 6338	Sta. 3 2-21-51 6339	Sta. 2 2-21-51 6340	Sta. 1 2-21-51 6341
BLUE-GREEN ALGAE												
Chroococcus dispersus							3,600	9,000	5,400	3,600	16,200	7,200
Oscillatoria spp.	16,200	149,400	86,400	33,750	14,400	10,800	27,000	19,800	64,800	34,200	25,200	21,600
GREEN ALGAE												
Actinastrum Hantzschii			5,400		1,800							
Ankistrodesmus							1,800				1,800	9,000
falcatus	21,600	7,200			5,400	1,800	3,600	5,400	1,800	1,800	5,400	1,800
Botryococcus Braunii								10,800	1,800			
Crucigenia quadrata				2,250	1,800	7,200			5,400			
Oocystis lacustris								3,600			3,600	
Pediastrum simplex												16,200
Scenedesmus abundans	1,350	1,800	3,600				3,600	7,200	1,800	5,400	5,400	3,600
Scenedesmus dimorphus					3,600	3,600						3,600
Scenedesmus quadricauda	2,700	1,800	1,800				1,800		3,600	5,400	9,000	1,800
DIATOMS												
Asterionella formosa							9,000	3,600		1,800	3,600	3,600
Cyclotella spp.	149,850	244,800	124,200	118,125	120,600	63,000	14,400	16,200	12,600	21,600	12,600	10,800
Cymbella spp.			1,800	1,125	1,800		1,800	1,800		3,600		
Fragilaria crotonensis							7,200	9,000				1,800
Gyrosigma attenuata			3,600	3,375	1,800	1,800						1,800
Melosira granulata			5,400	1,125			5,400		1,800			
Navicula spp.	35,100	39,600	37,800	31,500	46,800	14,400	48,600	21,600	19,800	16,200	9,000	28,800
Nitzschia spp.		7,200	1,800	1,125	3,600		9,000	7,200	1,800	1,800		
Surirella sp.								1,800				
Synedra spp.	8,100	32,400	30,600	25,875	14,400	12,600	19,800	3,600	5,400	16,200	10,800	1,800
Tabellaria fenestrata							10,800	3,600	1,800			
Tabellaria flocculosa										1,800		
PROTOZOA												
Chlamydomonas sp.	2,700	1,800	1,800						1,800			
Colpoda sp.			5,400							1,800	3,600	
Dinobryon sp.	1,350											
Euglena spp.			3,600									5,400
Holophyridae					3,600							
HOLOTRICHIDA	8,100	30,600	25,200	15,750	10,800	5,400	1,800	5,400	5,400	1,800	10,800	7,200
MASTIGOPHORA				3,375	5,400	5,400						
PERITRICHIDA		1,800										
Trachelomonas sp.		1,800										
Vorticella spp.	5,400	3,600	5,400	2,225		1,800					7,200	
ROTIFERA												
Keratella cochlearis									1,800			1,800
TOTALS	252,450	523,800	342,800	239,625	235,800	127,800	169,200	129,600	136,800	117,000	124,200	127,800

*Data from Minnesota Department of Health

APPENDIX F

SUMMARY OF INDIVIDUAL RESULTS

TABLE OF CONTENTS

Sub-Basin | Page

Souris River and Tributary 237

Red River of the North and Major Tributaries - 1950 and 1951 241

Red River of the North and Major Tributaries - 1938 and 1939[1] 248

Red River of the North and Major Tributaries - Chemical Data 250

---

[1] Red River of the North Research Investigation prepared by The North Dakota State Department of Health.

Preceding page blank

SOURIS RIVER SUB-BASIN

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station 1 Souris River	S. - 15	11:15 A 8/15/50	96	21	4.4	49	0.7	45	9.0	<25		
Bridge Highway #5 20 miles west of	"	2:05 P 8/16/50	98	20	7.6	83	3.2	330	9.0	<25		
Bottineau, N. D.	"	10:00 A 8/18/50	102	18	5.8	61	4.8	270	8.8	<25		
	"	9:45 A 8/22/50	103	17	7.7	79	5.0	200	8.9	<25		
	"	10:00 A 8/24/50	103	17	7.3	75	4.4	1,700	9.1	<25		
	"	1:20 P 1/30/51	155	0	2.7	18	4.2	54,000	7.6	<25	325	
	"	1:30 P 2/1/51	155	0	2.1	14	2.4	4,900	8.2	<25	284	
	"	12:10 P 2/2/51	155	0	2.5	17	2.8	2,200	8.0	<25	336	
Station 2 Souris River	S. - 75.2	1:05 P 8/15/50	76	23	6.5	75	2.1	1,700	8.3	95		
County Road Bridge 8 miles east of	"	8:40 A 8/16/50	81	21	8.0	89	4.4	790	8.5	70		
Bantry, N. D.	"	8:40 A 8/18/50	82	18	6.6	69	6.2	790	8.3	95		
	"	8:35 A 8/22/50	94	17	7.2	74	6.2	3,500	8.3	95		
	"	8:05 A 8/24/50	96	18	7.0	73	4.4	1,100	8.6	70		
	"	11:30 A 1/30/51	150	0	3.2	22	3.9	4,600	7.5	<25	320	
	"	1/31/51	150	0	3.0	21	-	-	-	-		
	"	11:45 A 2/1/51	150	0	3.2	22	2.6	3,300	7.9	<25	248	
	"	11:05 A 2/2/51	150	0	2.8	19	5.7	2,200	8.1	<25	344	
Station 3 Souris River	S. - 100.5	1:45 P 8/15/50	82	24	11.9	140	7.9	700	8.7	75		
Railroad Bridge North City Limits of	"	11:00 A 8/16/50	80	21	8.7	97	8.4	170	8.6	70		
Towner, N. D.	"	7:40 A 8/18/50	85	17	6.3	65	9.2	270	8.3	80		
	"	8:00 A 8/22/50	95	18	7.8	82	5.6	330	8.4	90		
	"	7:35 A 8/24/50	90	18	7.0	73	5.6	490	8.7	60		
	"	10:00 A 1/30/51	145	0	4.4	30	3.8	240,000	7.5	< 25	270	
	"	10:40 A 2/1/51	145	0	4.5	31	3.6	2,300	8.0	<25	240	
	"	10:10 A 2/2/51	145	0	4.1	28	2.4	4,900	7.8	<25	260	
Station 4 Souris River	S. - 178	3:00 P 8/15/50	75	23	10.6	122	7.8	3,500	8.7	95		
Foot bridge in Velva, N. D.	"	9:30 A 8/16/50	75	21	7.1	79	13.8	4,600	8.6	100		
	"	12:00 N 8/18/50	90	18	6.1	64	3.6	1,300	8.3	95		
	"	11:30 A 8/22/50	70	18	11.5	121	9.2	1,700	8.7	100		
	"	11:00 A 8/24/50	60	18	10.4	109	4.4	2,400	8.7	100		
	"	9:40 A 1/30/51	140	0	7.1	49	3.9	3,300	7.4	<25	254	
	"	9:45 A 1/31/51	140	0	7.4	51	2.5	3,300	7.7	<25		
	"	10:15 A 2/1/51	140	0	7.6	52	2.8	4,900	7.6	<25	264	
	"	10:00 A 2/2/51	140	0	7.1	49	3.0	3,400	8.2	<25	300	
Station 5 Souris River	S. - 192	3:25 P 8/15/50	60	23	5.5	63	6.2	2,300	8.1	160		
Bridge at Sawyer, N. D.	"	9:05 A 8/16/50	68	21	5.1	57	3.6	7,900	8.5	70		
	"	12:35 P 8/18/50	80	19	8.9	95	8.5	4,600	8.4	80		
	"	11:55 A 8/22/50	58	18	11.2	117	6.5	4,900	8.6	95		
	"	11:30 A 8/24/50	49	18	11.2	117	6.9	2,300	8.8	130		
	"	10:15 A 1/30/51	138	0	7.6	52	4.2	14,000	7.4	<25	260	

*Main stem mileage upstream from International Boundary.

Preceding page blank

SOURIS RIVER SUB-BASIN

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station 5 (Cont'd) Souris River	S. - 192	10:15 A 1/31/51	138	0	7.6	52	2.6	17,000	7.8	<25		
Bridge at Sawyer, N. D.	"	10:45 A 2/1/51	138	0	7.7	53	3.6	14,000	8.0	<25	264	
	"	10:15 A 2/2/51	138	0	7.6	52	3.0	7,900	7.9	<25	304	
Station 6 Souris River	S. - 206	3:45 P 8/15/50	55	23	3.6	41	2.2	11,000	8.0	120		
Bridge at Logan, N. D.	"	8:35 A 8/16/50	64	21	3.6	40	5.5	11,000	8.1	95		
	"	1:05 P 8/18/50	75	19	6.7	72	8.2	92,000	8.4	85		
	"	12:35 P 8/22/50	52	19	8.7	93	7.2	4,900	8.7	100		
	"	12:50 P 8/24/50	40	19	9.0	96	4.0	4,900	8.5	90		
	"	10:45 A 1/30/51	137	0	9.1	62	3.3	54,000	7.6	<25	258	
	"	10:45 A 1/31/51	137	0	8.9	61	3.0	14,000	7.9	<25		
	"	11:00 A 2/1/51	137	0	9.3	64	2.2	13,000	8.1	<25	264	
	"	11:05 A 2/2/51	137	0	9.0	62	3.7	13,000	7.8	<25	292	
Station 7 Souris River	S. - 214	4:05 P 8/15/50	52	24	9.9	116	4.2	54,000	8.4	85		
Bridge at Seugsted Farm 5 miles S.E. of	"	8:00 A 8/16/50	60	20	8.0	87	8.0	92,000	8.2	50		
Minot, N. D.	"	1:30 P 8/18/50	70	19	7.9	84	5.2	54,000	8.5	55		
	"	12:55 P 8/22/50	46	19	8.2	88	12.4	160,000	8.5	60		
	"	12:45 P 8/24/50	36	19	7.1	76	6.0	92,000	8.5	70		
	"	4:25 P 1/30/51	136	0	9.3	64	3.9	240,000	7.8	<25	248	
	"	11:20 A 1/31/51	136	0	9.6	66	3.9	28,000	7.8	<25		
	"	11:00 A 2/1/51	136	0	9.7	66	3.8	92,000	8.4	<25	260	
	"	11:05 A 2/2/51	136	0	9.7	66	3.2	35,000	8.0	<25	284	
Station 8 Souris River	S. - 236	7:30 A 8/15/50	50	20	6.0	65	0.7	1,300	8.1	70		
Bridge at Boy Scout Camp 4 miles west	"	8:45 A 8/16/50	58	20	6.1	67	4.6	5,400	8.3	160		
of Minot, N. D.	"	8:00 A 8/18/50	57	17	5.0	51	3.4	1,800	8.3	50		
	"	7:45 A 8/22/50	26	17	9.1	93	6.8	2,800	8.7	110		
	"	7:30 A 8/24/50	20	17	8.1	83	3.6	2,200	8.6	60		
	"	3:30 P 1/30/51	135	0	10.2	70	2.5	200	7.9	<25	254	
	"	12:50 P 1/31/51	135	0	10.6	72	2.4	450	7.9	<25		
	"	1:30 P 2/1/51	135	0	10.4	71	3.2	1,100	8.2	<25	260	
	"	1:00 P 2/2/51	135	0	10.5	72	2.6	450	8.2	<25	280	
Station A Des Lacs River	S. - 242.5 D.L. - 13.5	8:40 A 8/15/50	51	20	5.6	61	4.6	3,500	8.5	100		
Bridge in Foxholm, N. D.	"	9:45 A 8/16/50	50	20	6.0	65	6.2	16,000	8.7	250		
	"	9:00 A 8/18/50	24	18	6.4	67	7.3	9,200	8.4	150		
	"	9:00 A 8/22/50	14	17	6.6	68	13.8	24,000	8.6	170		
	"	8:45 A 8/24/50	11	17	6.6	68	7.2	3,500	8.7	130		
	"	2:40 P 1/30/51	10	0	3.5	24	2.6	1,400	7.8	35	502	
	"	1:40 P 1/31/51	10	0	3.6	25	3.2	1,100	7.2	40		
	"	2:15 P 2/1/51	10	0	3.4	23	1.9	780	7.9	30	520	
	"	1:30 P 2/2/51	10	0	3.0	21	3.2	1,700	8.3	30	436	

*Main stem mileage upstream from International Boundary.

SOURIS RIVER SUB-BASIN

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station 9 Souris River	S - 262	8:00 A 8/15/50	4	20	7.1	77	1.4	170	8.7	40		
Bridge 3 miles east of Foxholm, N. D.		9:15 A 8/16/50	4	21	8.9	99	8.1	490	8.4	40		
		8:40 A 8/18/50	4	18	8.2	86	2.9	2,400	8.7	35		
		8:30 A 8/22/50	4	18	10.1	106	5.5	5,400	8.9	45		
		8:30 A 8/24/50	4	17	6.7	69	2.8	16,000	9.0	45		
		2:05 P 1/30/51	130	0	10.6	72	2.2	200	7.7	<25	244	
		2:05 P 1/31/51	130	0	10.7	73	2.1	200	7.8	<25		
		2:00 P 2/1/51	130	0	10.0	68	2.7	200	8.3	<25	252	
		1:30 P 2/2/51	130	0	10.7	73	2.8	200	8.4	<25	268	
Station 10 Souris River	S - 308	9:20 A 8/15/50	60	21	6.2	69	9.9	40	9.2	50		
Bridge Highway #25 1/2 mile north of		11:25 A 8/16/50	75	21	8.2	91	13.6	140	8.2	55		
Greene, N. D.		10:00 A 8/18/50	65	18	6.5	68	7.5	790	8.8	55		
		10:15 A 8/22/50	44	17	6.6	68	9.2	470	8.9	50		
		11:00 A 8/24/50	33	18	6.0	63	8.2	1,300	8.7	55		
Station 11 Souris River	S - 324	9:45 A 8/15/50	70	21	7.4	82	1.1	140	8.5	<25		
Bridge Highway #5 12 miles west of		12:00 N 8/16/50	65	21	4.2	47	4.5	18	8.1	<25		
Mohall, N. D.		11:00 A 8/18/50	55	20	5.5	60	6.7	1,700	8.2	<25		
		11:30 A 8/22/50	38	19	5.9	63	4.0	5,400	8.3	<25		
		10:00 A 8/24/50	28	19	6.8	73	5.6	220	8.4	<25		
		3:05 P 1/30/51	6	0	1.0	7	4.3	11,000	7.7	<25	440	
		2:10 P 2/1/51	6	0	0.6	4	2.0	2,300	8.1	<25	452	
		2:12 P 2/2/51	6	0	0.5	3	1.7	2,300	8.0	<25	300	

*Main stem mileage upstream from International Boundary.

SOURIS RIVER SUB-BASIN

LABORATORY DATA

SEASONAL AVERAGES

Sampling point	Mileage from Mouth*	Date 1950-51	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N.** Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.
					p.p.m.	% Sat.					
Station 1	S - 15										
Summer Average			100	19	6.6	69	3.6	270	9.0	<25	
Winter Average			155	0	2.4	16	3.1	4,900	7.9	<25	315
Station 2	S - 75.2										
Summer Average			86	19	7.1	76	4.7	1,100	8.4	85	
Winter Average			150	0	3.0	21	4.1	3,300	7.8	<25	304
Station 3	S - 100.5										
Summer Average			86	20	8.3	91	7.3	330	8.5	75	
Winter Average			145	0	4.3	30	3.3	4,900	7.8	<25	257
Station 4	S - 178										
Summer Average			74	19	9.1	99	7.8	2,400	8.6	100	
Winter Average			140	0	7.3	50	3.0	3,400	7.7	<25	273
Station 5	S - 192										
Summer Average			63	20	8.4	90	6.3	4,600	8.5	110	
Winter Average			138	0	7.6	52	3.4	14,000	7.8	<25	276
Station 6	S - 206										
Summer Average			57	20	6.3	68	5.4	11,000	8.3	100	
Winter Average			137	0	9.1	62	3.0	14,000	7.8	<25	271
Station 7	S - 214										
Summer Average			53	20	8.2	90	7.1	92,000	8.4	65	
Winter Average			136	0	9.6	66	3.7	92,000	8.0	<25	264
Station 8	S - 236										
Summer Average			42	18	6.9	72	3.8	2,200	8.4	90	
Winter Average			135	0	10.4	71	2.7	450	8.0	<25	265
Station A	S - 242.5 DL - 13.5										
Summer Average			30	18	6.2	66	7.8	9,200	8.6	160	
Winter Average			10	0	3.4	23	2.7	1,200	7.8	35	486
Station 9	S - 262										
Summer Average			4	19	8.2	87	4.1	2,400	8.7	40	
Winter Average			130	0	10.5	72	2.4	200	8.0	<25	255
Station 10	S - 308										
Summer Average			55	19	6.7	72	9.7	470	8.8	55	
Station 11	Sn - 324										
Summer Average			51	20	6.0	65	4.4	220	8.3	<25	
Winter Average			6	0	0.7	5	2.7	2,300	7.9	<25	397

*Main stem mileage upstream from International Boundary.

**Median value.

RED RIVER SUB-BASIN

1950-1951

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
Station A Pembina River	Red R - 2.8 P.R. - 0.3	9:05 A 8/21/50	350	15	8.9	88	1.6	-	8.4	290		
Bridge in City of Pembina, N. D.	"	9:14 A 8/22/50	345	16	8.7	87	0.5	680	8.2	290		
	"	9:35 A 8/23/50	340	15	8.7	86	1.3	7,000	8.1	250		
	"	1/9/51	45	0	5.3	36	0.7	1,300	7.6	<25	380	
	"	1/10/51	45	0	4.8	33	1.3	2,300	7.4	<25	400	
	"	1/11/51	45	0	5.1	35	2.8	450	7.3	<25	388	
Station 1 Red River	Red R - 3.0	9:30 A 8/21/50	3,580	17	8.1	83	0.2	-	8.3	320		
Highway Bridge at Pembina, N. D.	"	9:34 A 8/22/50	3,380	18	8.0	84	0.1	1,100	8.2	360		
	"	9:55 A 8/23/50	3,230	17	8.0	82	0.4	3,300	8.3	270		
	"	1/9/51	2,080	0	9.4	64	0.9	450	7.8	<25	220	
	"	1/10/51	2,080	0	9.6	66	2.2	680	7.7	<25	228	
	"	1/11/51	2,080	0	9.7	66	4.1	230	7.6	<25	215	
Station B Two Rivers	Red R - 20 Two R - 6.2	9:05 A 8/21/50	35	15	8.6	85	1.0	-	8.4	140		
Bridge on River Road 9 miles south of	"	10:11 A 8/22/50	34	16	8.2	82	0.7	1,700	8.2	150		
Humbolt, Minn.	"	10:30 A 8/23/50	33	15	8.5	84	1.9	3,300	8.2	150		
	"	1/9/51	8.7									
	"	1/10/51	8.7	0	4.0	27	2.5	2,200	7.4	160	456	
	"	1/11/51	8.7	0	4.2	29	3.0	3,300	7.5	75	388	
Station 2 Red River	Red R - 53	11:05 A 8/21/50	2,840	18	7.8	82	0.1	-	8.3	210		
Highway Bridge Drayton, N. D.	"	11:08 A 8/22/50	2,760	19	7.7	82	0.4	3,100	8.2	200		
	"	11:28 A 8/23/50	2,620	18	7.9	83	0.8	13,000	8.2	200		
	"	9:58 A 8/24/50	2,520	17	7.8	80	0.6	7,900	8.2	200		
	"	1/9/51	1,990	0	10.2	70	0.7	3,300	7.8	<25	220	
	"	1/10/51	1,990	0	10.3	70	2.6	13,000	7.5	<25	228	
	"	1/11/51	1,990	0	10.2	70	2.5	3,300	7.7	<25	110	
Station C Tamarack River	Red R - 65 Ta.R. - 2.0	12:14 P 8/21/50	-	16	8.8	88	3.5	-	8.4	240		
Bridge on River Road 5 miles south of	"	12:12 P 8/22/50	-	19	9.3	99	3.1	1,100	8.3	160		
Robin, Minn.	"	12:18 P 8/23/50	-	18	9.1	95	3.8	3,300	8.0	170		
	"	10:31 A 8/24/50	-	14	8.0	77	3.0	3,300	8.1	160		
Station D Park River	Red R - 67 Pk. R. - 1.2	8:10 A 8/21/50	2	12	9.1	84	>8.8	-	8.4	250		
Highway #44 Crossing N.E. of Grafton, N.D.	"	8:16 A 8/22/50	2	15	8.8	87	>8.7	1,300	7.8	240		
	"	8:38 A 8/23/50	2	12	10.1	93	>9.3	4,900	8.4	240		
	"	8:55 A 8/24/50	2	13	9.2	87	>8.0	4,900	8.0	220		
Station E Snake River	Red R - 75 Sn. R. - 1.2	1:06 P 8/21/50	-	17	11.2	115	6.5	-	8.5	95		
Bridge on River Road 14 miles south of	"	7:46 A 8/22/50	-	19	12.4	133	6.6	200	8.3	110		
Robin, Minn.	"	8:10 A 8/23/50	-	17	11.0	113	7.1	610	8.4	95		
	"	8:24 A 8/24/50	-	16	9.1	91	6.3	200	8.5	120		
	"	1/10/51	-	0	0.5	3	3.8	1,300	7.5	<25	216	
	"	1/11/51	-	0	0.8	5	2.0	200	7.4	<25	444	

*Main stem mileage upstream from International Boundary.

RED RIVER SUB-BASIN

1950-1951

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D.	Coliforms M.P.N.	pH	Turb.	Alkal.	
					p.p.m.	% Sat.	p.p.m.	Per 100 ml.		p.p.m.	p.p.m.	
Station H (Cont'd) Red Lake River	Red R. - 143 R.L.R. - 0.5	3:35 P 8/24/50	1,480	18	7.3	77	0.7	7,000	8.1	120		
Water Plant Intake East Grand Forks,	"	1/9/51	1,660	0	11.4	78	4.5	4,900	7.5	<25	176	
Minn.	"	1/10/51	1,720	0	12.5	85	1.3	7,900	7.6	<25	180	
	"	1/11/51	1,660	0	12.6	86	2.7	7,000	7.8	<25		
Station 7 Red River	Red R.-145-7	4:08 P 8/21/50	1,050	19	7.8	83	1.2	-	8.4	95		
Water Plant Intake Grand Forks, N. D.	"	3:30 P 8/22/50	1,000	18	6.8	71	4.5	1,800	8.3	100		
	"	3:30 P 8/23/50	950	18	6.6	69	1.4	2,000	8.4	95		
	"	3:00 P 8/24/50	900	16	7.9	79	1.2	2,300	8.4	100		
	"	1/9/51	500	0	0.1	0.7	4.0	780	7.6	35	330	
	"	1/10/51	500	0	0.1	0.7	3.3	1,300	7.7	<25	344	
	"	1/11/51	500	0	0.1	0.7	2.4	1,100	7.6	<25	360	
Station 8 Red River	Red R. - 180	3:03 P 8/21/50	1,000	18	7.7	80	1.9	-	8.2	320		
Highway Bridge Climax, N. D.	"	2:28 P 8/22/50	950	19	8.0	86	2.8	6,800	8.3	290		
	"	2:30 P 8/23/50	900	18	7.2	75	2.4	7,800	8.4	290		
	"	2:10 P 8/24/50	850	16	7.9	79	2.4	4,900	8.3	260		
	"	1/9/51	450	0	1.4	10	1.9	2,300	7.5	<25	328	
	"	1/10/51	450	0	1.6	11	1.9	1,700	7.5	<25	352	
	"	1/11/51	450	0	1.4	10	1.9	7,900	7.5	<25	352	
Station JA Marsh River	Red R. - 202 Ma.R. - 2.8	2:15 P 8/21/50	92	16	8.7	87	1.0	-	8.2	100		
Highway #81 Crossing Shelley, Minn.	"	1:50 P 8/22/50	81	17	8.6	88	1.0	2,000	8.3	120		
	"	1:55 P 8/23/50	85	17	8.5	87	1.2	2,000	8.3	100		
	"	1:30 P 8/24/50	86	15	8.2	81	6.9	1,300	8.4	120		
	"	1/9/51	60	0	5.0	34	2.1	3,300	7.5	<25	340	
	"	1/10/51	64	0	6.2	42	1.3	2,300	7.4	<25	336	
	"	1/11/51	62	0	5.6	38	2.2	3,300	7.6	<25	340	
Station 1 Goose River	Red R. - 203 G.R. - 22.0	2:40 P 8/21/50	8	17	11.5	118	3.0	-	8.4	80		
Highway #81 Crossing Hillsboro, N. D.	"	2:00 P 8/22/50	8	18	10.1	106	3.8	2,000	8.3	75		
	"	2:15 P 8/23/50	7	19	11.8	126	4.2	680	8.4	70		
	"	1:45 P 8/24/50	9	15	10.1	100	4.0	2,300	8.4	80		
	"	1/9/51	6.7	0	5.4	37	1.4	3,300	7.4	<25	488	
	"	1/10/51	6.7	0	5.3	36	1.9	1,400	7.4	<25	484	
	"	1/11/51	6.7	0	5.5	38	2.1	22,000	7.3	<25	488	
Station 9 Red River	Red R.- 220.4	1:28 P 8/21/50	900	18	7.7	81	3.2	-	8.3	250		
Highway Bridge Halstad, Minn.	"	1:25 P 8/22/50	850	19	7.6	81	2.8	4,500	8.4	290		
	"	1:15 P 8/23/50	800	18	7.4	78	2.8	4,500	8.4	330		
	"	1:05 P 8/24/50	750	16	7.8	78	3.4	3,300	8.3	260		
	"	1/9/51	340	0	0.6	4	1.4	2,300	7.6	<25	328	
	"	1/10/51	340	0	1.2	8	2.0	1,100	7.5	<25	340	
	"	1/11/51	340	0	1.6	11	2.4	780	7.6	<25	344	

*Main stem mileage upstream from International Boundary.

Preceding page blank

RED RIVER SUB-BASIN

1950-1951

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling point	Mileage from Mouth*	Date	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station J Minnesota	Red R. - 225 W.R.R.- 3.0	1:28 P 8/21/50	3.8	16	8.6	86	0.7	-	8.3	40		
Wild Rice River Highway #81 Crossing	"	1:05 P 8/22/50	3.0	18	9.1	95	0.8	2,000	8.4	40		
	"	1:35 P 8/23/50	2.2	15	8.2	81	0.6	2,000	8.4	30		
	"	1:25 P 8/24/50	5.0	14	8.3	80	1.2	4,900	8.4	35		
Station 10 Red River	Red R. - 261.4	12:45 P 8/21/50	700	18	8.0	84	4.1	-	8.4	260		
Highway Bridge Georgetown, Minn.	"	11:55 A 8/22/50	650	18	8.0	84	3.2	11,000	8.4	310		
	"	11:55 A 8/23/50	600	18	6.4	67	3.8	33,000	8.4	280		
	"	11:45 A 8/24/50	550	16	6.6	66	5.7	92,000	8.4	270		
	"	1/9/51	250	0	3.2	22	1.1	4,600	7.6	<25	348	
	"	1/10/51	250	0	3.4	23	3.2	3,300	7.3	<25	344	
	"	1/11/51	250	0	3.6	25	2.9	4,900	7.4	<25		
Station K Buffalo River	Red R. - 262.5 Buf.R.- 2.0	1:55 P 8/21/50	11	14	9.2	89	0.4	-	8.4	35		
2 miles north of Georgetown, Minn.	"	12:05 P 8/22/50	10	16	8.4	84	1.0	2,000	8.4	55		
	"	12:05 P 8/23/50	9	14	8.6	83	3.8	2,000	8.2	55		
	"	8/24/50	9	14	7.9	76	1.8	2,300	8.3	80		
	"	1/9/51	16	0	0.6	4	1.4	200	7.6	<25	380	
	"	1/10/51	15	0	1.2	8	1.2	180	7.5	<25	392	
	"	1/11/51	15	0	0.3	2	1.6	230	7.5	<25	380	
Station L Sheyenne River	Red R. - 273 Shy.R.- 11.0	12:30 P 8/21/50	125	16	9.4	94	2.6	-	8.5	65		
Highway #81 crossing north of Harwood, N. D.	"	11:40 A 8/22/50	120	17	9.8	101	3.0	2,000	8.4	95		
	"	11:35 A 8/23/50	115	16	9.4	94	3.0	4,500	8.4	110		
	"	8/24/50	110	15	7.6	75	6.4	7,900	8.4	140		
	"	1/9/51	54	0	5.9	40	1.4	3,300	7.6	<25	404	
	"	1/10/51	53	0	6.1	42	1.1	7,900	7.6	<25	408	
	"	1/11/51	54	0	6.0	41	2.2	11,000	7.6	<25	408	
Station 11 Red River	Red R. - 286	11:55 A 8/21/50	400	18	7.1	74	4.1	-	8.4	160		
County Road crossing 2 miles north	"	11:15 A 8/22/50	320	19	7.1	76	5.2	130,000	8.3	180		
Fargo, N.D. Sewage Plant	"	11:15 A 8/23/50	310	19	7.0	75	5.2	920,000	8.6	180		
	"	8/24/50	270	17	5.6	57	5.8	350,000	8.3	160		
	"	1/9/51	135	0	6.9	47	4.9	54,000	7.6	<25	296	
	"	1/10/51	135	0	7.4	51	6.8	160,000	7.6	<25	296	
	"	1/11/51	135	0	8.2	56	5.0	54,000	7.6	<25	300	
Station 12 Red River	Red R. - 298	11:00 A 8/21/50	383	18	8.7	91	3.8	-	8.4	120		
Fargo Water Plant Intake, Fargo, N. D.	"	10:35 A 8/22/50	303	18	9.1	95	3.6	450	8.4	160		
	"	10:30 A 8/23/50	303	18	9.7	102	4.1	450	8.2	110		
	"	8/24/50	257	17	8.2	84	3.4	200	8.4	120		
	"	1/9/51	130	0	10.4	71	0.6	450	7.4	<25	300	
	"	1/10/51	130	0	10.8	74	1.6	200	7.7	<25	292	
	"	1/11/51	130	0	10.9	75	2.1	680	7.5	<25	300	

*Main stem mileage upstream from International Boundary.

RED RIVER SUB-BASIN

LABORATORY DATA

SEASONAL AVERAGES

Sampling point	Mileage from Mouth*	Date 1950-51	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms** M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station A	Red R - 2.8 P.R. - 0.3											
Summer Average			345	15	8.8	87	1.1	3,500	8.2	280		
Winter Average			45	0	5.1	35	1.6	1,300	7.4	<25	389	
Station 1	Red R - 3.0											
Summer Average			3,397	17	8.0	83	0.2	2,200	8.3	320		
Winter Average			2,080	0	9.6	65	2.4	450	7.7	<25	221	
Station B	Red R - 20 Two R - 6.2											
Summer Average			34	15	8.4	84	1.2	2,500	8.3	150		
Winter Average			8.7	0	4.1	28	2.8	2,800	7.4	120	422	
Station 2	Red R - 53											
Summer Average			2,685	18	7.8	82	0.5	7,900	8.2	200		
Winter Average			1,990	0	10.2	70	1.9	3,300	7.7	<25	186	
Station C	Red R - 65 Ta.R. - 2.0											
Summer Average				17	8.8	90	3.4	3,300	8.2	180		
Station D	Red R - 67											
Summer Average			2	13	9.3	88	8.7	4,900	8.2	240		
Station E	Red R - 75 Sn.R. - 1.2											
Summer Average				17	10.9	112	6.6	200	8.4	100		
Winter Average				0	0.6	4	2.9	800	7.4	<25	330	
Station 3	Red R - 77											
Summer Average			2,585	18	7.7	81	0.6	7,900	8.3	200		
Winter Average			1,970	0	10.5	72	1.8	11,000	7.6	<25	217	
Station F	Red R - 88 Fl.R. - 3.0											
Summer Average			7	15	6.3	62	5.5	1,100	8.2	180		
Station 4	Red R - 116											
Summer Average			2,490	18	7.8	83	0.8	24,000	8.2	160		
Winter Average			1,930	0	11.4	78	2.1	17,000	7.6	<25	218	
Station 5	Red R - 129											
Summer Average			2,458	18	8.1	86	1.2	54,000	8.2	120		
Winter Average			1,920	0	11.5	79	2.8	54,000	7.6	<25	264	
Station 6A	Red R - 138											
Summer Average			2,418	18	8.4	88	1.7	49,000	8.1	120		

*Main stem mileage upstream from International Boundary.

**Median value.

RED RIVER SUB-BASIN

LABORATORY DATA

SEASONAL AVERAGES

Sampling point	Mileage from Mouth *	Date 1950-51	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms** M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station 6	Red R - 141											
Summer Average			2,380	18	7.9	83	2.4	49,000	8.2	95		
Winter Average			1,900	0	11.2	76	2.2	4,900	7.6	<25	211	
Station H	Red R - 143 R.L.R.- 0.5											
Summer Average			1,488	18	7.8	83	2.4	7,900	8.2	120		
Winter Average			1,680	0	12.2	83	2.8	7,000	7.6	<25	178	
Station 7	Red R - 145-7											
Summer Average			975	18	7.3	76	2.1	2,000	8.4	100		
Winter Average			500	0	0.1	0.7	3.2	1,100	7.6	<25	345	
Station 8	Red R - 180											
Summer Average			925	18	7.7	80	2.4	6,800	8.3	290		
Winter Average			450	0	1.5	10	1.9	2,300	7.5	<25	336	
Station JA	Red R - 202 Ma.R - 2.8											
Summer Average			86	16	8.5	86	2.5	2,000	8.3	110		
Winter Average			62	0	5.6	38	1.9	3,300	7.5	<25	339	
Station 1	Red R - 203 G.R.- 22.0											
Summer Average			8	17	10.9	112	3.7	2,000	8.4	75		
Winter Average			6.7	0	5.4	37	1.8	3,300	7.4	<25	487	
Station 9	Red R - 220.4											
Summer Average			825	18	7.6	80	3.0	4,500	8.4	280		
Winter Average			340	0	1.1	8	1.9	1,100	7.6	<25	337	
Station J	Red R - 225 W.R.R. -3.0											
Summer Average			3.5	16	8.6	86	0.8	2,000	8.4	35		
Station 10	Red R - 261.4											
Summer Average			625	18	7.2	75	4.2	33,000	8.4	280		
Winter Average			250	0	3.4	23	2.4	4,600	7.4	<25	346	
Station K	Red R - 262.5 Buf.R - 2.0											
Summer Average			10	14	8.5	83	1.8	2,000	8.3	55		
Winter Average			15	0	0.7	5	1.4	200	7.5	<25	384	
Station L	Red R - 273 Shy.R - 11.0											
Summer Average			118	16	9.0	91	3.8	4,500	8.4	100		
Winter Average			54	0	6.0	41	1.6	7,900	7.6	<25	407	
Station 11	Red R - 286											
Summer Average			325	18	6.7	70	5.1	350,000	8.4	170		
Winter Average			135	0	7.5	51	5.6	54,000	7.6	<25	297	

*Main stem mileage upstream from International Boundary.

**Median value.

RED RIVER SUB-BASIN

LABORATORY DATA

SEASONAL AVERAGES

Sampling point	Mileage from Mouth*	Date 1950-51	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N.** Per 100 ml.	pH	Turb. p.p.m.	Alkal. p.p.m.	
					p.p.m.	% Sat.						
Station 12	Red R - 298											
Summer Average			312	18	8.9	93	3.7	450	8.4	130		
Winter Average			130	0	10.7	73	1.4	450	7.5	<25	297	

---

*Main stem mileage upstream from International Boundary.

**Median value.

RED RIVER SUB-BASIN

1938-1939

LABORATORY DATA

SUMMARY OF AVERAGE RESULTS

Sampling point	Mileage from Mouth*	Date 1938-39	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.		
					p.p.m.	% Sat.	p.p.m.					
Station 1	Red R. - 3	12/1/38 to 4/1/39	226	0.0	0.38	2.6	5.0	4,200	7.6	16		
Red River		4/1/39 to 7/1/39	1,839	12.4	8.77	81.2	3.9	1,800	8.2	260		
Hwy. bridge at Pembina, N.Dak.		8/1/39 to 10/1/39	209	17.5	8.7	90.7	3.0	200	8.6	105		
Station 2	Red R. - 53	12/1/38 to 4/1/39	240	0.0	0.45	3.1	5.1	5,900	7.6	15		
Red River		4/1/39 to 7/1/39	1,810	13.0	9.23	87.6	3.6	600	8.3	190		
Hwy. bridge at Drayton, N.Dak.		8/1/39 to 10/1/39	184	17.5	7.6	78.8	3.0	350	8.4	113		
Station 3	Red R. - 77	12/1/38 to 4/1/39	260	0.0	0.72	4.9	5.2	4,100	7.6	14		
Red River		4/1/39 to 7/1/39	1,708	13.3	9.2	87.7	4.2	1,900	8.2	162		
Hwy. #17 crossing E. of Grafton, N.D.		8/1/39 to 10/1/39	180	17.5	7.9	82.0	2.2	250	8.4	75		
Station 4	Red R. - 116	12/1/38 to 4/1/39	252	0.0	1.9	13.0	5.6	8,100	7.6	11		
Red River		4/1/39 to 7/1/39	1,606	13.7	7.7	71.0	4.0	27,700	8.0	176		
Hwy. bridge at Oslo, Minn.		8/1/39 to 10/1/39	167	19.0	6.6	70.2	4.2	2,000	8.0	185		
Station 5	Red R. - 129	12/1/38 to 4/1/39	275	0.0	3.8	25.8	5.2	16,600	7.6	11		
Red River		4/1/39 to 7/1/39	1,580	13.7	7.9	72.7	3.4	79,500	8.1	161		
River bank directly E. of Manuel N. Dak.		8/1/39 to 10/1/39	170	18.0	4.35	45.1	3.7	175,000	8.0	121		
Station 6	Red R. - 141	12/1/38 to 4/1/39	280	0.0	4.05	27.7	6.1	14,200	7.7	31		
Red River - above		4/1/39 to 7/1/39	1,575	14.0	7.27	67.0	3.8	26,900	8.1	173		
W. end of Riverside Park Dam, Grand Forks, N. Dak.		8/1/39 to 10/1/39	171	19.8	6.1	65.8	4.2	16,400	8.2	50		
Station H	Red R. - 143 R.L.R. -0.5	12/1/38 to 4/1/39	153	0.0	3.25	22.4	1.4	8,500	7.6	14		
Red Lake River		4/1/39 to 7/1/39	484	14.0	7.47	71.3	2.9	920	8.2	90		
Water plant intake East Grand Forks, Minn.		8/1/39 to 10/1/39	144	19.5	7.7	82.8	4.6	4,300	8.4	43		
Station 7	Red R. -145-7	12/1/38 to 4/1/39	127	0.0	3.25	22.2	2.0	330	7.8	11		
Red River		4/1/39 to 7/1/39	1,091	14.0	8.13	76.2	3.5	560	8.2	158		
Water plant intake Grand Forks, N.D.		8/1/39 to 10/1/39	27	20.5	7.05	77.2	4.0	660	8.4	56		
Station 8	Red R. - 180	12/1/38 to 4/1/39	208	0.0	1.85	12.7	1.7	790	7.6	16		
Red River		4/1/39 to 7/1/39	938	13.7	9.17	85.5	4.3	1,200	8.2	240		
Hwy. bridge W. of Climax, Minn.		8/1/39 to 10/1/39	29	18.2	7.85	83.0	3.2	4,800	8.4	161		
Station 9	Red R. -220.4	12/1/38 to 4/1/39	248	0.0	2.87	19.7	2.2	2,500	7.7	26		
Red River		4/1/39 to 7/1/39	859	13.3	9.87	92.3	4.2	2,100	8.2	201		
Hwy. bridge at Halstad, Minn.		8/1/39 to 10/1/39	32	18.5	7.4	78.0	3.0	390	8.4	106		
Station J	Red R. - 225 W.R.R. - 3	12/1/38 to 4/1/39	26	0.0	3.5	23.9	1.6	270	7.6	13		
Minn.Wild Rice River		4/1/39 to 7/1/39	145	12.3	9.2	82.2	2.0	1,200	8.2	82		
Hwy. #81 crossing in Minnesota		8/1/39 to 10/1/39	15	19.5	7.4	79.9	1.6	730	8.4	66		

*Main stem mileage upstream from International Boundary.

RED RIVER SUB-BASIN

1938-1939

LABORATORY DATA

SUMMARY OF AVERAGE RESULTS

Sampling point	Mileage from Mouth*	Date 1938-39	Ave. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.		
Station 10	Red R.- 261.4	12/1/38 to 4/1/3	282	0.0	4.85	33.2	3.1	14,000	7.6	23		
Red River		4/1/39 to 7/1/39	658	13.0	9.17	84.7	4.4	15,600	8.2	148		
Hwy. bridge at Georgetown, Minn.		8/1/39 to 10/1/39	17	18.5	9.8	103.7	8.0	1,700	8.6	179		
Station K	Red R.- 262.5	12/1/38 to 4/1/39	45	0.0	0.42	2.9	1.0	1,100	7.5	28		
Buffalo River	Buf. R. - 2	4/1/39 to 7/1/39	125	12.3	9.03	82.1	2.5	340	8.2	44		
Hwy bridge 2 mi. N. of Georgetown, Minn.		8/1/39 to 10/1/39	2	17.5	7.7	79.9	2.2	2,100	8.5	65		
Station L	Red R. - 273 Shy.R. - 11	12/1/38 to 4/1/39	32	0.0	5.15	35.2	2.7	7,000	7.6	24		
Sheyenne River		4/1/39 to 7/1/39	128	12.3	9.3	85.2	4.6	4,200	8.2	90		
Hwy. #81 crossing N. of Harwood, N.D.		8/1/39 to 10/1/39	10	18.5	6.75	71.5	4.8	1,200	8.4	85		
Station 11	Red R. - 286	12/1/38 to 4/1/39	242	0.0	8.7	60.2	8.6	24,400	7.8	32		
Red River		4/1/39 to 7/1/39	355	13.6	9.17	85.8	5.2	641,000	8.0	74		
Co. road crossing 2 mi. N. of Fargo, N.Dak. sewage plant		8/1/39 to 10/1/39	11	20.5	3.7	40.9	10.6	852,000	8.2	76		
Station 12	Red R. - 298	12/1/38 to 4/1/39	242	0.2	9.55	65.5	2.4	560	7.7	20		
Red River		4/1/39 to 7/1/39	355	13.8	9.23	86.6	3.8	430	8.2	74		
Water plant intake Fargo, N. Dak.		8/1/39 to 10/1/39	12	21.7	7.65	86.3	5.0	1,000	8.6	34		

*Main stem mileage upstream from International Boundary.

RED RIVER SUB-BASIN

CHEMICAL DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Date	Total Solids	Total Alka-linity	Total Hard-ness	Iron	Cal-cium	Mag-nes-ium	Sodium	Fluo-ride	Chlo-ride	Sul-fate	Bicar-bonate	Carbon Di-oxide	pH	Ni-trate	MPN per 100 ml
Station 12	7-15-49	198	110	124	3.0	30.8	11.4	0	.07	3.1	4.9	134.5	0		Trace	
Red River - Fargo Water Plant Intake	8-15-49	394	212	292	1.38	48.0	41.8	0	.2	18.0	22.5	258.5		7.9	4.3	
	9-15-50	359.3	214.0	264	1.35	35.2	42.8	0	.15	14.0	0	261.5		8.1	4.4	
	10-14-50	424	230	290	.60	48.0	36.5	7.3	.25	6.5	44.5	281		7.5	Trace	
	11-15-49	441.7	226.4	440.1	.4	75.5	61.0	9.0	.25	8.5	5.6	276.0		7.25	0	
	12-15-49	420.5	242.0	272.3	.3	63.0	28.0	17.5	.25	16.0	Trace	295.5		7.9	0	
	1-12-50	549.8	308.0	225.1	.2	49.0	25.0	50.9	.2	11.0	33.4	376.0		8.2	4.3	1,300
	2-15-50	583.6	280	257.2	.29	57.0	28.0	30.0	.15	22.0	39.1	342,0		7.7	65.0	1,100
	4-11-50	170.2	86.0	118.7	1.2	21.6	13.0	Trace	Trace	0	16.6	105.0		7.1	10.9	79
	5-16-50	331	146	231		45	29	25	0	2	52.3	178	Trace	8.2	Trace	
	6-16-50	438.8	188	320		54.0	45.0	18	0	4.0	88.8	230		8.22	Trace	
	7-17-50	281.0	163	256.8	0.95	32.0	43.0	5.00	.2	1.6		129.0	0	7.4	Trace	
	8-21-50	329.8	199.4	258.3	.72	37.6	40.0	4.0	0	4.0	0	243.5		8.0	Trace	
Station 7	6-20-49	511.0	216.0	280	1.3	56.0	34.1	33.2	.3	19.0	103.8	264.0		8.2	Trace	
Red River Grand Forks	7-20-49	341.0	176.0	205.6	2.5	50.0	22.0	6.05	.3	12.0	34.6	214.2	0		Trace	210
Water Supply Intake	8-20-49	370.0	222.0	270	.78	53.1	33.4	0	.3	12.0	0	271.0		8.2	Trace	79
	10-24-49	486.6	268.0	262	.36	58.2	28.5	34.0	.25	32.0	0	327		7.6	Trace	1,300
	11-22-49	498.0	262.0	285	.4	59.2	33.0	21.0	.25	31.0	33.6	300		8.3	Trace	9,200
	12-27-49	648.8	316.0	232	.26	80.0	30.0	51.0	.2	27.0	72.5	388		7.7	Trace	700
	1-10-50	666.9	334.0	343	.25	80.0	36.0	34.8	.1	26.2	50.2	407		8.0	32.5	490
	2-22-50	584.0	308	257.2	.3	65.0	23.0	34.5	.15	29.6	56.0	351	7.2	8.3	17.4	9,200
	3-22-50	462	266	309	1.3	45	48	23		14	33.5	271	26.4	8.6		230
	4-22-50	318	156	231		45	29	21	0	2	31.5	190	Trace	8.2		79
	5-21-50	139	88	102.5		18	14	0	0	0	0	107		7.7		170
	6-21-50	387	205.8	278	8.8	52	36	36.8	.3	Trace	Trace	251		7.2	2.1	1,800
	7-20-50	342.4	197.6	269.2	2.8	37	43	13.8		4.8	Trace	241	Trace	7.3	Trace	11,000
	8-21-50	499	219.8	431.5	.95	67.5	64.0	28.0	.1	12.0	58.4	268.0		7.9		2,300
	9-21-50	414	230	285	.8	55.0	36	20	.1	5.2	15.8	281.5		8.0		
Station H	6-20-49	360	194	304	1.4	80.0	25	6.7	.29	3.0	117.0	236.0		8.0	Trace	
Red Lake River East Grand Forks	7-20-49	475.8	202.0	288.0	1.18	68.8	28.0	17.3	.3	10.0	103.8	246.5		8.1	Trace	56
Water Plant Intake	8-20-49	342.0	201.0	248	.28	59.0	24.4	0	.3	10.0	0	245.0		8.1		2,400
	9-20-49	344.4	202.0	236	.6	56.0	28.0	Trace	.3	13.0	0	246.5		7.7		640
	10-24-49	305.0	190.0	263.4	.36	46.5	11.5	0	.25	12.0	0	232		7.8		24,000
	11-22-49	350.7	184.0	236.0	.68	57.0	22.9	0	.25	18.0	27.9	224.0		8.15	Trace	24,000
	12-27-49	456.6	214.0	234.6	.35	69.5	14.0	34.5	.2	4.8	72.5	261.0		8.0		9,200
	1-10-50	428.13	204.0	210.5	.25	63.0	13.0	28.4	.25	4.8	56.0	254.0		8.0	8.68	1,800
	2-23-50	353.0	202	319.7	.18	50.0	23.0	0	.15	6.0	27.9	246.0		8.2		2,400
	March	No sample collected														
	4-22-50	220.5	126	214		38	29	0	0	0	0	153.5	0			640
	5-22-50	259.2	164	125.7		33.0	10.5	0	0	0	15.7	200		7.9		1,800
	6-21-50	294.6	169.8	246.0	1.95	55	26.5		.2	4.0	0	207		7.4	Trace	1,800
	7-20-50	293.6	175.8	248.0	1.8	45	33		0	0	0	214		7.0		4,900

RED RIVER SUB-BASIN

CHEMICAL DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Date	Total Solids	Total Alkalinity	Total Hardness	Iron	Calcium	Magnesium	Sodium	Fluoride	Chloride	Sulfate	Bicarbonate	Carbon Dioxide	pH	Nitrate	MPN per 100ml
Station H (Cont'd)	8-21-50	285.6	162.8	272.5	.7	43.2	40		.1	3.6		198		7.5	Trace	7,900
	9-21-50	244	157.8	148.6	2.65	34	15.5		.1	0	0	192		8.0	Trace	
Sheyenne River Valley City	8-12-49	336.8	196	208	.69	48	21.4	9.6		16.0	9.9	224	7.2	8.3	Trace	11,000
	9-21-49	599	238	248	0	41.6	33.1	65.1	.27	42.4	133.4	290	0	8.0	13.0	49,000
	10-24-49	1151.3	422.0	332.8	.58	64.0	42.0	155.3	.3	142.4	212.0	515.0	0	6.9	Trace	92,000
	1-1-50	823.6	328.0	330.7	0	83.0	30.0	102.5	.1	24.1	184.0	400.0	0	7.9		7,900

APPENDIX G

Laboratory Tests and their Significance

Temperature - The temperature of a water is one of the factors which controls oxygen solubility and thus saturation level of dissolved oxygen in a stream. The rate of natural purification and bacterial growth is affected by changes in temperatures.

Turbidity - Turbidity of water is due to suspended matter, either particles that will settle out or colloidal and nonsettleable. Turbidity measurements give an approximation of the amount of silt or suspended material carried by a stream. To a limited extent a correlation exists between turbidity, suspended matter, and high and low stream stages. Turbidity also results from plankton growths.

pH - pH is defined as the negative logarithm of hydrogen ion concentration. The pH value indicates relative acidity or alkalinity, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acids, above pH 7.0 the presence of alkalies.

Alkalinity - The alkalinity of a water usually indicates the presence of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. In comparison with pH, alkalinity is generally assumed to be a quantity factor while pH is considered an intensity factor.

Dissolved Oxygen - Normally the amount of oxygen dissolved in stream water is limited by the saturation value (9.17 ppm. at 20° C. and 760 mm. barometric pressure) which is a function of water temperature, but in some cases as a result of the photosynthetic action of some water plants, including algae, this value may be exceeded, causing supersaturation. Dissolved oxygen must be present to support fish and aquatic life, and for the natural aerobic purification of stream waters, the minimum quantity permissible depending on the quality of water desired. Satisfactory methods of waste disposal to the streams depend on the relationship between character, quantity, and strength of the wastes, and the character and volume of the receiving stream. Varying dissolved oxygen values below the saturation level are an indication of the presence of organic, and possibly chemical, pollution which utilizes oxygen from the stream. A measure of the degree of pollution of a particular area is given by deficiency in dissolved oxygen content below saturation.

Biochemical Oxygen Demand - The standard test for biochemical oxygen demand (B.O.D.) requires five-day incubation in total darkness at 20° C. of sealed samples of the water under examination, and determination of the loss of dissolved oxygen during that time. Where the loss may be greater than the initial dissolved oxygen present, the sample is diluted with a standard dilution water having no appreciable oxygen demand of its own, and the measured loss multipled by the appropriate dilution factor. The B.O.D. thus determined becomes a measure of the amount of oxygen necessary to satisfy the biochemical oxidation requirements of the pollution present at the time the sample was collected. Since the amount of dissolved oxygen present decreases with rising temperatures, while, at the same time, the rate of biochemical oxidation increases, critical stream conditions result during warm months, particularly when high temperatures are combined with low stream flows.

Hardness - Water is rendered hard principally by the presence of calcium and magnesium, chiefly in the form of bicarbonates and sulphates, but occassionally as chlorides and nitrates and is expressed as "carbonate" and "noncarbonate" hardness. The sum of these two is the total hardness. Hardness in waters usually has little to do with health, but becomes of major economic importance from an industrial and household standpoint.

Coliform Group Organisms - This determination gives the most accurate estimation of the degree of pollution by sanitary sewage. These coliform bacteria are present in the intestines of warm blooded animals and are discharged in vast numbers in human feces, which constitute the main source of these bacteria in sewage.

Laboratory Procedures

Chemical and bacteriological examinations and analyses were made in accordance with "Standard Methods for the Examination of Water and Sewage" Ninth Edition, 1946, of the American Public Health Association.

APPENDIX H

Definition of Terms

1. Acre foot. A volume of water one acre in area and one foot deep.

2. Cubic foot per second (cfs) or second foot. A measure of the rate of discharge relating volume to time.

3. Population Equivalent (P. E.). 0.167 pounds of 5-day 20° C., B.O.D. per day, the amount usually attributable to wastes from one person.

4. Parts per million (ppm.). One part in a million parts of water by weight or 1 milligram per liter.

5. Plankton. An assemblage of microscopic organisms that live suspended in water.

6. Benthos. Animals dwelling on the bottoms of various bodies of water.

7. Periphyton. Growths of microscopic organisms forming oozy or gelatinous coatings upon submerged objects or on bottoms of lakes and streams.

8. Algae. Microscopic primitive plants other than fungi that occur in plankton, periphyton, and as floating mats. This definition has been restricted for usage in this report.

9. Monocarbonate Alkalinity. Alkalinity due to the presence of the monocarbonate (CO_3) ion expressed as ppm. calcium carbonate.

10. Bicarbonate Alkalinity. Alkalinity due to the presence of bicarbonate (HCO_3) ion expressed as ppm. calcium carbonate.

11. Mean sea level (m.s.l.). A mean level to which, at a certain stage of the tide, the sea water returns and is used as a reference datum.